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• POPULAR FEATURES •
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Our May 2012 issue will be published on Thursday 5 April 2012, see page 72 for details.

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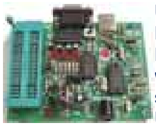
PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

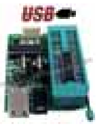
Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU121) £24.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

USB & Serial Port PIC Programmer



USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
Kit Order Code: 3149EKT - **£49.95**
Assembled Order Code: AS3149E - **£59.95**
Assembled with ZIF socket Order Code: AS3149EZIF - **£74.95**

USB Flash/OTP PIC Programmer



USB PIC programmer for a wide range of Flash & OTP devices—see website for details. Free Windows Software. ZIF Socket and USB lead not included. Supply: 16-18Vdc.
Assembled Order Code: AS3150 - **£49.95**
Assembled with ZIF socket Order Code: AS3150ZIF - **£64.95**

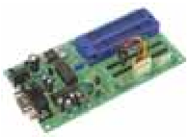
ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
Kit Order Code: 3123KT - **£28.95**
Assembled Order Code: AS3123 - **£39.95**

Introduction to PIC Programming

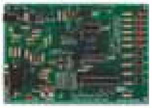
Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.
Kit Order Code: 3081KT - **£16.95**
Assembled Order Code: AS3081 - **£24.95**

PIC Programmer Board



Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied.
Kit Order Code: K8076KT - **£39.95**

PIC Programmer & Experimenter Board



The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
Kit Order Code: K8048KT - **£39.95**
Assembled Order Code: VM111 - **£59.95**

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU303 £9.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055KT - **£39.95**
Assembled Order Code: VM110 - **£64.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two & *Ten Channel versions also available.*
Kit Order Code: 3180KT - **£54.95**
Assembled Order Code: AS3180 - **£64.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£24.95**
Assembled Order Code: AS3145 - **£31.95**
Additional DS1820 Sensors - **£4.95 each**

Remote Control Via GSM Mobile Phone

Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£14.95**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£79.95**
Assembled Order Code: AS3140 - **£94.95**

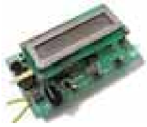
8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
Kit Order Code: 3108KT - **£74.95**
Assembled Order Code: AS3108 - **£89.95**

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£64.95**
Assembled Order Code: AS3142 - **£74.95**

Audio DTMF Decoder and Display



Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU303). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£37.95**
Assembled Order Code: AS3153 - **£49.95**

3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone option and 2-wire serial interface for microcontroller or PC communication with simple command set. Suitable for common anode RGB LED strips, LEDs and incandescent bulbs. 56 x 39 x 20mm. 12A total max. Supply: 12Vdc.
Kit Order Code: 3191KT - **£27.95**
Assembled Order Code: AS3191 - **£37.95**

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

4-Channel Serial Port Temperature Monitor & Controller Relay Board

4 channel computer serial port temperature monitor and relay controller with four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay channels provide output control. Relays are independent of sensor channels, allowing flexibility to setup the linkage in any way you choose. Commands for reading temperature and relay control sent via the RS232 interface using simple text strings. Control using a simple terminal / comms program (Windows HyperTerminal) or our free Windows application software.
Kit Order Code: 3190KT - **£84.95**
Assembled Order Code: AS3190 - **£99.95**

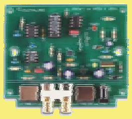
40 Second Message Recorder

Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Standalone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24 Vdc operation. Just change one resistor for different recording duration/sound quality. sampling frequency 4-12 kHz.
Kit Order Code: 3188KT - **£29.95**
Assembled Order Code: AS3188 - **£37.95**
120 second version also available

Bipolar Stepper Motor Chopper Driver

Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.
Kit Order Code: 3187KT - **£39.95**
Assembled Order Code: AS3187 - **£49.95**

Video Signal Cleaner



Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.
Kit Order Code: K8036KT - **£32.95**
Assembled Order Code: VM106 - **£49.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

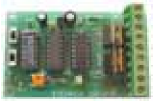
Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

DC Motor Speed Controller (100V/7.5A)

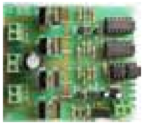
Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - **£19.95**
Assembled Order Code: AS3067 - **£27.95**

Computer Controlled / Standalone Unipolar Stepper Motor Driver



Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£16.95**
Assembled Order Code: AS3179 - **£23.95**

Computer Controlled Bi-Polar Stepper Motor Driver



Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - **£24.95**
Assembled Order Code: AS3158 - **£34.95**

Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
Kit Order Code: 3166v2KT - **£23.95**
Assembled Order Code: AS3166v2 - **£33.95**

AC Motor Speed Controller (600W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 600 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.
Kit Order Code: 1074KT - **£15.95**
Assembled Order Code: AS1074 - **£23.95**

See www.quasarelectronics.com for lots more motor controllers

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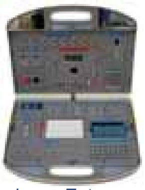
500-in-1 Electronic Project Lab



Top of the range. Complete self-contained electronics course. Takes you from beginner to 'A' Level standard and beyond! Contains all the hardware and manuals to assemble 500 projects. You get 3 comprehensive course books (total 368 pages) - *Hardware Entry Course*, *Hardware Advanced Course* and a microprocessor based *Software Programming Course*. Each book has individual circuit explanations, schematic and connection diagrams. Suitable for age 12+.
Order Code EPL500 - **£199.95**
Also available: 30-in-1 **£19.95**, 50-in-1 **£29.95,** 75-in-1 **£39.95** £130-in-1 **£49.95** & 300-in-1 **£89.95** (see website for details)

Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Advanced Personal Scope 2 x 240MS/s

Features 2 input channels - high contrast LCD with white backlight - full auto set-up for volt/div and time/div - recorder roll mode, up to 170h per screen - trigger mode: run - normal - once - roll ... - adjustable trigger level and slope and much more.
Order Code: APS230 - ~~£499.95~~ **£399.95**

Personal Scope 10MS/s

The Personal Scope is not a graphical multimeter but a complete portable oscilloscope at the size and the cost of a good multimeter. Its high sensitivity - down to 0.1mV/div - and extended scope functions make this unit ideal for hobby, service, automotive and development purposes. Because of its exceptional value for money, the Personal Scope is well suited for educational use.
Order Code: HPS10 - ~~£189.95~~ **£159.95**

See website for more super deals!

No.1 for KITS

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Secure Online Ordering Facilities • Full Product Listing, Descriptions & Photos • Kit Documentation & Software Downloads

Everyday Practical Electronics FEATURED KITS

April 2012

Everyday Practical Electronics Magazine has been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are 'bullet proof' and already tested Down Under. All Jaycar kits are supplied with specified board components, quality fibreglass tinned PCBs and have clear English instructions. Watch this space for future featured kits.

Stereo Compressor Kit

KC-5507 £21.75 plus postage & packing

Compressors are useful in eliminating the extreme sound levels during TV ads, "pops" from microphones when people speak or bump / drop them, leveling signals when singers or guitarist vary their level, etc. Kit includes PCB, processed case and electronic components for 12VDC operation. 12VDC plug pack required - use MP-3147 £6.25

NEW

Featured in EPE January 2012

Minimaximite Controller Kit

KC-5505 £18.25 plus postage & packing

A versatile and intelligent controller to interface with your creations, such as home automation. Features 20 configurable digital/analog I/O ports, 128K RAM and 256KB flash memory to hold your program and data. Design and test in MMBasic over a USB link from your PC, then disconnect the PC and the programs continue to operate. Alternatively, hard wire a PC monitor, keyboard, SD card reader and amplified speaker to work independent of a PC.

- Requires 2.3 - 3.6VDC (2 x AA or use plugpack MP-3310 £7.00)
- Kit supplied with PCB, pre-programmed and pre-soldered micro, and electronic components
- PCB: 78(L) x 38(W)mm

NEW

Featured in EPE December 2011

Ultrasonic Antifouling for Boats

KC-5498 £90.50 plus postage & packing

Marine growth electronic antifouling systems can cost thousands. This project uses the same ultrasonic waveforms and virtually identical ultrasonic transducers mounted in a sturdy polyurethane housings. By building it yourself (which includes some potting) you save a fortune! Standard unit consists of control electronic kit and case, ultrasonic transducer, potting and gluing components and housings. The single transducer design of this kit is suitable for boats up to 10m (32ft); boats longer than about 14m will need two transducers and drivers. Basically all parts supplied in the project kit including wiring. (Price includes epoxies).

- 12VDC
- Suitable for power or sail
- Could be powered by a solar panel/wind generator
- PCB: 104(L) x 78(W)mm

Featured in EPE January 2012

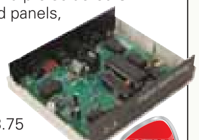
Now available Pre-built:

Dual output, suitable for vessels up to 14m (45ft)
YS-5600 £309.25
Quad output, suitable for vessels up to 20m (65ft)
YS-5602 £412.25

Digital Audio Delay Kit

KC-5506 £36.25 plus postage & packing

Corrects sound and picture synchronization ("lip sync") between your modern TV and home theatre system. Features an adjustable delay from 20 to 1500ms in 10ms steps, and handles Dolby Digital AC3, DTS and linear PCM audio with sampling rate of up to 48kHz. Connections include digital S/PDIF and optical Toslink connections, and digital processing means there is no audio degradation. Kit includes PCB with overlay and pre-soldered SMD IC, enclosure with machined panels, and electronic components.



- 9-12VDC power supply required
- Universal IR remote required - use AR-1729 £8.75
- PCB: 103(L) x 118(W)mm

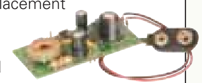
NEW

Featured in EPE August 2011

3 - 9VDC to DC Converter Kit

KC-5391 £6.00 plus postage & packing

This great little converter allows you to use regular Ni-Cd or Ni-MH 1.2V cells, or Alkaline 1.5V cells for 9V applications. Using low cost, high capacity rechargeable cells, the kit will pay for itself in no-time! You can use any 1.2-1.5V cells you desire. Imagine the extra capacity you would have using two 9000mAh D cells in replacement of a low capacity 9V cell.



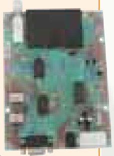
- PCB: 59(L) x 29(W)mm
- Kit supplied with PCB, and all electronic components.

Featured in EPE June 2007

Full Function Smart Card Reader / Programmer Kit

KC-5361 £20.00 plus postage & packing

Program both the microcontroller and EEPROM in the popular gold, silver and emerald wafer cards. Card used needs to conform to ISO-7816 standards. Powered by 9-12VDC wall adaptor or a 9V battery (not included). Instructions outline software requirements that are freely available on the internet.



- PCB: 141 x 101mm
- Kit supplied with PCB, wafer card socket and all electronic components
- Suitable Wafer Card available, ZZ-8800

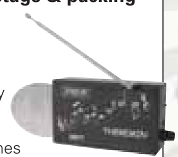
Note: Jaycar Electronics will not accept responsibility for the operation of this device, its related software, or its potential to be used for unlawful purposes.

Featured in EPE May 2006

Theremin Synthesiser Kit MkII

KC-5475 £27.25 plus postage & packing

The ever-popular Theremin is better than ever! From piercing shrieks to menacing growls, create your own eerie science fiction sound effects by simply moving your hand near the antenna. It's now easier to build with PCB-mounted switches and pots to reduce wiring to just the hand plate, speaker and antenna and has the addition of a skew control to vary the audio tone from distorted to clean.



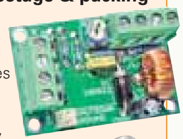
- Complete kit contains PCB with overlay, pre-machined case and all specified components
- PCB: 145(L) x 85(W)mm

Featured in EPE March 2011

Switching Regulator Kit

KC-5508 £14.50 plus postage & packing

Outputs 1.2 to 20V from a higher voltage DC supply at currents up to 1.5A. It is small, efficient and with many features including a very low drop-out voltage, little heat generation, electronic shutdown, soft start, thermal, overload and short circuit protection. Kit supplied with PCB, pre-soldered surface mounted components and PCB mount components.



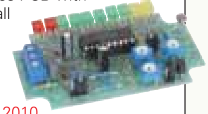
NEW

- PCB: 49.5 x 34mm

Voltage Monitor Kit

KC-5424 £8.50 plus postage & packing

This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your car. The kit features 10 LEDs that illuminate in response to the measured voltage, preset 9-16V, 0.-5V or 0-1V ranges, complete with a fast response time, high input impedance and auto dimming for night time driving. Kit includes PCB with overlay, LED bar graph and all electronic components.



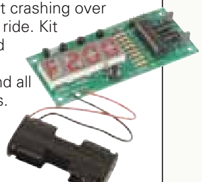
- 12VDC
- PCB: 74 x 47mm

Featured in EPE September 2010

G-Force Meter Kit

KC-5504 £18.25 plus postage & packing

Measure the g-forces on your vehicle and it's occupants during your next lap around the race circuit, or use this kit to encourage smoother driving to save petrol and reduce wear & tear. Forces (+/-2g) are displayed on the 4-digit LED display. Also use it to measure g-forces on a boat crashing over waves or on a theme park thrill ride. Kit includes PCB with pre-mounted SMD component, pre-programmed microcontroller and all onboard electronic components.



- Requires 2 x AA batteries
- PCB: 100(L) x 44(W)mm

Note: We supply the PCB with the SMD component already mounted on the board to save time and frustration.

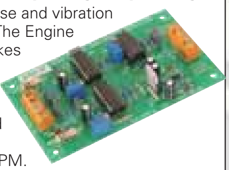
NEW

Featured in EPE November 2011

Marine Engine Speed Equaliser Kit

KC-5488 £14.50 plus postage & packing

Avoid unnecessary noise and vibration in twin-engine boats. The Engine Speed Equaliser Kit takes the tacho signals from each motor and displays the output on a meter that is centred when both motors are running at the same RPM. When there's a mismatch, the meter shows which motor is running faster and by how much. Simply adjust the throttles to suit. Short form kit only, requires moving coil panel meter (QP-5010 £6.25).



- 12VDC
- Kit supplied with PCB, and all electronic components
- PCB: 105(L) x 63(W)mm

Featured in EPE November 2011

Jaycar Electronics

Freecall order: 0800 032 7241

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EVERYDAY PRACTICAL ELECTRONICS

A jump start for those new to electronics

EPE aims to provide you with challenging and engaging projects. We also take advantage of the rapid pace of change in electronics – the 'smart' functions that many of our designs include would have been unimaginable or impractically expensive and complicated just a few years ago. Internet servers, GPS-based circuits and very high quality audio designs are just a handful of the stimulating projects and areas we have covered over the last year.

While these projects have undoubtedly been successful, and we enjoy your positive feedback in letters or via enthusiastic banter in our online forum *Chat Zone*, we are aware that for some readers, projects at this level are perhaps a little daunting. The circuits and theory behind our projects are typically sophisticated and not always appropriate for beginners contemplating their first foray into soldering.

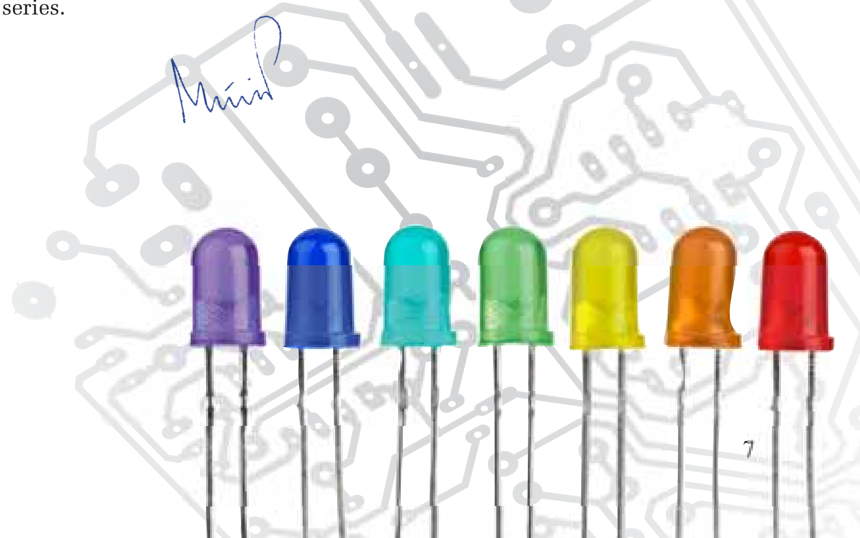
We try hard to cater for all levels of ability, and so we've decided to run a series dedicated to beginners, which features straightforward, engaging and easy-to-build circuits. It's called 'Jump Start' and it begins in next month's issue.

Authored by *EPE* stalwarts Mike and Richard Tooley, *Jump Start* will provide a practical introduction to the design and realisation of simple, but useful electronic circuits. It will appeal to self-taught newcomers, or those following formal courses taught in schools and colleges. It will also be ideal for involving a son or daughter in their first steps into our fascinating hobby.

Those of you who enjoyed our recent *Teach-In* series will feel at home with *Jump Start*, with its carefully paced explanations and use of the excellent 'Circuit Wizard' software. Each project will include design notes, with just the right level of theory to aid understanding; suggestions for modifying and expanding the project; and photographs explaining each stage of manufacture.

May's issue will kick off with a *Moisture Alarm* – the perfect project for the great British summer! Subsequent projects will include a quiz machine, solar mobile phone charger, Christmas lights, a logic probe, simple radio… Well you get the picture, it will be fun, educative and practical.

For more experienced readers, who are perhaps worried that *Jump Start* is not really for you, fear not! We are adding an extra eight pages to every issue of *EPE*; so no sections are being cut to make space for this new series.



NEWS

A roundup of the latest Everyday News from the world of electronics

Apple power by Barry Fox

Seasoned Apple watchers learn that the Cupertino company sometimes files 'left-field' patents for off-the-wall ideas, perhaps to mislead competitors or even have some mischievous fun with gullible reporters. But when the company files a clutch of patents on a new line of development, credited to the same several inventors, it's a safe bet that Apple is hoping to commercialise the idea. A bunch of recent filings clearly point to the upcoming use of fuel cells to power Apple's portables.

In two patents filed in April 2010, US 2011/0256465 and US 2011/0256463, inventors Vijay Iyer, Jean Lee, Gregory Tice, Bradley Spare and Steven Michalske explain why designers have hitherto been wary of using fuel cells in laptops.

Each cell converts fuel such as hydrogen into electricity, with water as the waste product. So stainless steel electrodes are needed to avoid corrosion. Each cell only generates around 0.5V, so 25 cells are stacked in series to sum the voltage and deliver the 12V to 17.5V needed to power the device. Since stainless steel is heavy, the weight of the stack becomes prohibitive for a portable device. Also, if one cell fails the voltage drops below the critical level that the player needs and the whole stack becomes useless as a power supply.

Apple's patented tricks include saving weight by bonding a cathode on one side of a stainless steel plate and an anode on the other. Also, fewer cells are used and they are connected in parallel rather than series, to deliver low voltage at meaty power to a voltage step-up converter. If one cell in the stack fails, the delivered voltage remains the same; the only penalty is slightly reduced current and thus slightly reduced power time.

Replaceable power

In June 2010, Spare, Iyer, Lee and Tice joined with Michael Hillman and David Simon to file for 2011/0311895 and 2011/0313589, which worry about US dependence on oil from the Middle East and offshore drilling. They also note that the EPEAT (electronic product environmental assessment tool) score for consumer devices can be increased by providing them with renewable energy sources such as hydrogen fuel cells, which use replaceable cartridges of sodium borohydride that can power a laptop for 'days or even weeks'.

Another problem with fuel cells, they say, is that they take time to 'boot-up' and start producing power. So Apple's plan is to build a small capacity conventional Li-Ion rechargeable booster battery to provide short bursts of instant-on power.

For reliability and safety, the fuel cell and boost battery must be integrated with an intelligent link to the computer processor. This three-way link lets the computer monitor the fuel cell charge level and its internal pressure and temperature, along with the boost battery state, while controlling a cooling fan inside the fuel cell stack.

Taken together, Apple's four filings leave little doubt that the company is serious about using fuel cells for future portable devices, most likely laptops and tablets that have the space on board for the cell stack and associated electronics.

Apple has obviously been planning for the use of fuel cells for several years. A 2006 filing (2007/0201703) notes the increasing use of speaker docks with portable players designed for use with headphones or ear buds. Unless powered separately, the dock draws far more current than the ear transducers, so the portable 'battery or mini-fuel cell' soon flattens. The 2006 filing describes intelligence to be used in the player, which controls the output sound level dependent on the amount of charge left.

littleBits

From New York comes 'littleBits', an opensource library of electronic modules that snap together with tiny magnets for prototyping and play. It's simple enough for young children to play with, but has enough variety and components for any age to enjoy.

They claim, 'we spend more than 7.5 hours with technological devices every day, but most us don't know how they work, or how to make our own. For all the interactivity of these devices, we are bound to passive consumption.' The designers of littleBits want to put a stop to this. Their aim is to 'create scientific thinkers and problem-solvers'.

littleBit's, a kind of 'electronic Lego'

The circuit boards are engineered to snap together without soldering, wiring, or programming. There are over 50 littleBits modules, divided into four categories:

- Power components, to provide electricity to the system
- Input components, to interpret data or their surroundings
- Output components, to make visual, physical, and audible changes to their surroundings
- Wire components route power and communication between the bits

More details at: **http://littlebits.cc**

Star Trek-style scanners!

Scientists have developed a new way to create electromagnetic terahertz (THz) waves or T-rays – the technology behind full-body security scanners. The researchers behind the study, published recently in the journal Nature Photonics*, say their new stronger and more efficient continuous wave T-rays could be used to make better medical scanning equipment, and may one day lead to innovations similar to the 'tricorder' scanner used in* Star Trek.

In the study, researchers from the Institute of Materials Research and Engineering, a research institute in Singapore, and Imperial College London have made T-rays into a much stronger directional beam than was previously thought possible, and have done so at room-temperature conditions. This is a breakthrough that should allow future T-ray systems to be smaller, more portable, easier to operate, and much cheaper than current devices.

The scientists say that the T-ray scanner and detector could provide part of the functionality of a Star Trek-like medical 'tricorder' – a portable sensing, computing and data communications device – since the waves are capable of detecting biological phenomena, such as increased blood flow around tumorous growths. Future scanners could also perform fast wireless data communication to transfer a high volume of information on the measurements it makes.

T-rays are waves in the far infrared part of the electromagnetic spectrum that have a wavelength hundreds of times longer than those that make up visible light. Such waves are already in use in airport security scanners, prototype medical scanning devices and in spectroscopy systems for materials analysis.

T-rays can sense molecules such as those present in cancerous tumours and living DNA, since every molecule has its unique signature in the THz range. They can also be used to detect explosives or drugs, for gas pollution monitoring, or non-destructive testing of semiconductor integrated circuit chips.

Current T-ray imaging devices are very expensive and operate at only a low output power, since creating the waves consumes large amounts of energy and needs to take place at very low temperatures.

In the new technique, the researchers demonstrated that it is possible to produce a strong beam of T-rays by shining light of differing wavelengths on to a pair of electrodes – two pointed strips of metal separated by a 100nm gap on top of a semiconductor wafer. The structure of the tip-to-tip nano-sized gap electrode greatly enhances the THz field and acts like a nano-antenna to amplify the wave generated.

The scientists are able to tune the wavelength of the T-rays to create a beam that is useable in the scanning technology.

Quadcopter lift-off

Parallax has launched an exciting new kit; the ELEV-8 Quadcopter is a flying robotic platform that is lifted and propelled by four fixed rotors. There are no fixed wings; all of the lift is created from the rotors.

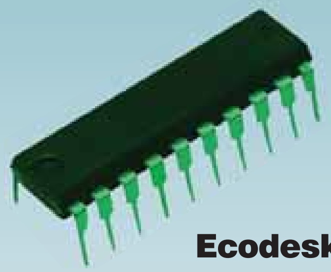
Unlike standard helicopters, a quadcopter uses fixed-pitch blades, whose rotor pitch does not vary as the blades rotate. Control of vehicle motion is achieved by varying the relative speed of each rotor to change the thrust and torque produced by each.

The quadcopter uses a HoverFly board, with a Propeller multicore microprocessor to electronically control stabilisation of the aircraft. The benefits to this system are a stable platform, with no mechanical linkages for a small maneuverable and agile aircraft.

The kit provides an inexpensive way to get involved in the quadcopter arena. The kit includes: frame, mounting hardware, motors, speed controllers, propellers and the control board for flight stabilisation (the only thing you need to provide is a battery and the RC radio equipment – a six-channel RC radio is recommended).

The ELEV-8 platform is large enough for outdoor flight and has plenty of room for payload and attachments (up to 0.9kg). The Price is US$550; for more details visit: **www.Parallax.com**

Parallax's new ELEV-8 Quadcopter Kit



Ecodesk

Eco saint or sinner? – find out at ecodesk.com

If you are interested in the 'sustainability' of a company in the electronics sector, a new online database may be just what you are looking for. With over 5,000 company profiles, **ecodesk.com** is a website that allows members of every industry worldwide to compare and communicate sustainability – see: **www.ecodesk.com/sector/electronics**

3-axis automotive gyro

Gyros aid cars navigate if a GPS signal is lost

STMicroelectronics, a supplier of MEMS (micro-electro-mechanical systems) sensors and automotive ICs, has introduced the market's first 3-axis digital-output gyroscope that meets the industry-standard qualification for automotive integrated circuits (AEC-Q100). Their latest angular-rate sensor aims to add positioning accuracy and stability to a wide range of automotive applications, including in-dash navigation, telematics and vehicle tolling systems.

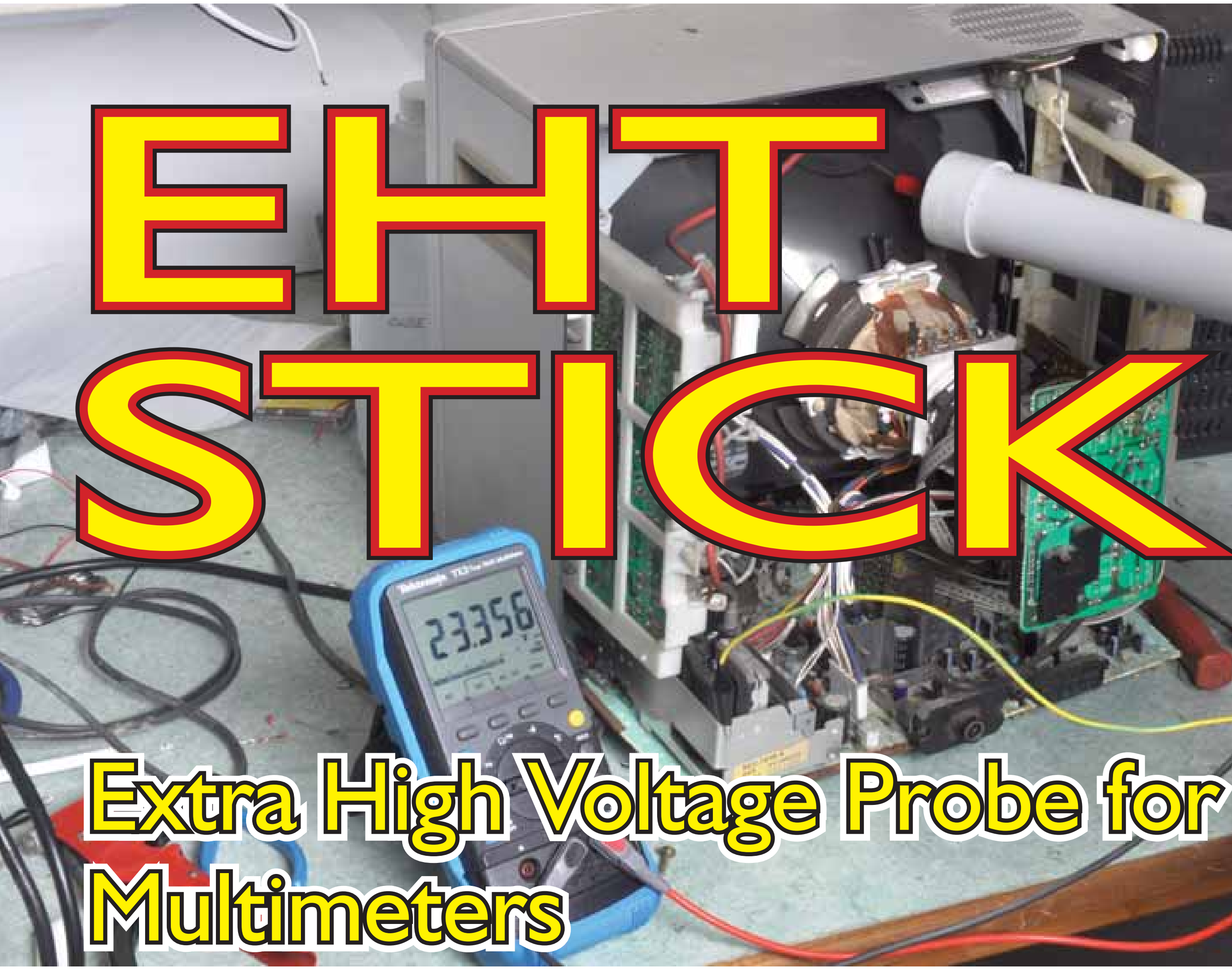
Accurate measurements of angular-motion detection with gyroscopes can significantly enhance dead-reckoning and map-matching capabilities in car navigation and telematics applications. In situations when a GPS signal can't be seen, such as in urban canyons between tall buildings, dead-reckoning systems compensate for loss of satellite signal by monitoring motion, distance travelled and altitude.

Free MIT course

Just announced as we go to press, MIT, the prestigious Massachusetts Institute of Technology is offereing a free online course in electronics. You'll need some physics and basic calculus, but if you are after a challenge, then this might be just right; enroll at: **http://mitx.mit.edu**

EHT STICK

Extra High Voltage Probe for Multimeters



Do you need to measure the EHT voltage in a CRT-based scope, computer monitor or TV receiver, or perhaps in a photocopier, laser printer or microwave oven? You'll need an EHT probe to suit your digital multimeter (DMM) to do this, and you'll find they are pretty pricey. Not to worry though, because here's one you can build for less than £40.

MEASURING really high voltages is not something you can normally do easily or safely. So, if you want to measure the EHT of CRT-based TV receivers, or the corona voltages in photocopiers or laser printers, what do you do?

These voltages are around 22kV or more – far out of the range of a DMM. If you want to measure the voltage in a microwave – about 3kV or so – that's also way out of range of a DMM.

You can't make this kind of measurement with a normal multimeter or DMM, because in most cases they have a maximum input voltage rating of 1000V DC or 750V AC.

The only way this type of meter can be used to make measurements on higher voltages is to connect a specially designed EHT divider probe between its input sockets and the source of high voltage. The probe divides down the voltage to be measured by a known factor (usually either 100:1 or 1000:1), to bring it within the voltage range that can be handled safely by the meter.

This type of EHT divider probe has been available commercially for many

years, and they're still available if you hunt them down.

They've never been particularly cheap though, and if you want to buy a brand-new probe nowadays you'll find they're priced from around £100 and up – not easy to justify if you only want to measure EHT voltages every now and again.

EHT stick

Our probe, which we've dubbed the 'EHT Stick', has been designed to allow you to measure DC voltages up to around 23kV to 25kV, using any standard digital multimeter (DMM) which has an input resistance of 10MΩ. It provides a division ratio of 1000:1, so

SAFETY WARNING

In order to use EHT divider probes like the one described in this article safely, you MUST note carefully the following points:

1. **The probe's ground return MUST always be connected** securely to the 'earthy' side of the EHT circuit in which you are making the measurement – **BEFORE** you connect the probe's measuring tip to the 'hot' side of the circuit. This is most important, because if the probe tip is connected first, all of the probe's internal circuitry AND YOUR DMM will be 'floating' at the full EHT voltage, and thus represent a very serious safety risk.

2. The probe's ground return lead and its connection clip must be regarded as a vitally important part of the probe itself. It is crucial to achieving correct probe operation, because it provides the only connection between the bottom end of the probe's voltage divider and the EHT circuit in which you are making the measurement.

3. NEVER connect the probe's ground return lead to the 'hot' side of the high voltage circuit, as this will also cause your DMM to be floating at the full EHT voltage. If you need to measure an EHT voltage that happens to be negative with respect to ground, simply reverse the polarity of the probe lead connections to the DMM input jacks. The probe's ground return lead should ALWAYS be connected to the 'cold' or earthy side of the EHT circuit.

4. If at all possible, turn off the power to the EHT circuit before you connect the probe's ground return lead and input measuring tip. Only turn the power back on when both connections are secure and your hands are safely withdrawn. This will help ensure that you don't receive a shock when the probe tip comes into contact with the 'hot' side of the EHT circuit, and also that a 'flashover' arc cannot develop.

5. Turn off the power to the EHT circuit again after you have made the measurement, and before you remove the tip and ground return connections (in that order).

6. If it is not feasible to turn off the power to the EHT circuit before making the probe connections, and you have to hold the probe body in your hand while making the measurement, you must make sure you hold it down at the output lead end. Do not risk a flashover or punch-through by holding it closer to the tip end.

7. **Do not attempt to use this type of probe to make measurements in high voltage power distribution systems.** These can supply a huge amount of energy/power and, in most cases, cannot be turned off in order to make the probe connections. The risk of serious injury or death is therefore extremely high.

Test setup using the EHT Stick and a digital multimeter. You must always ensure that the green grounding lead is firmly attached to a suitable ground point in the circuit under test BEFORE probing the EHT.

kilovolts at the input are read simply as volts on the DMM.

Like many commercial EHT probes, it provides an input resistance of just over 800MΩ. So, when it's connected across a circuit with a voltage of say 20kV (20,000V), the probe will draw a modest 'loading' current of only 25μA.

In their divider's crucial input leg, commercial EHT probes have always used special very high value 'long spiral' resistors rated to withstand very high voltages, but these haven't been readily available for some time.

So instead, we have used 80 (yes, eighty!) *high voltage* (3.5kV) 10MΩ 0.5W 1% metal film resistors in series, to produce the 800MΩ input leg. The Farnell type number for the 10MΩ is 1772424.

Because of the large number of resistors in series, the voltage drop per resistor is kept well within their maximum voltage rating.

Even when the EHT Stick is measuring a voltage of 25kV for example, the voltage across each resistor in the input leg is only 313V. The power dissipation per resistor will be less than 10mW.

By the way, don't be tempted to substitute standard 0.25W or 0.5W resistors for the high voltage types specified. Most 0.25W and 0.5W resistors have a voltage rating of only 200V to 250V or so – certainly not enough!

Before we move on to look at the probe's circuit and how it's built and used, please read the text in the safety warning box carefully.

Making measurements in EHT circuits inevitably presents an increased safety risk, because even in a CRT-based TV set or a microwave oven, the EHT circuitry can provide a lethal shock.

So it's important – in fact, *vital* – that you not only build the probe exactly as we describe, but also you follow the correct procedures when making a measurement. If you are hasty, careless, or ignore our advice, the measurement may be the last you ever make!

Circuit description

As you can see from the EHT Stick circuit diagram of Fig.1, the probe is just a resistive voltage divider, with an input leg formed by the 80 10MΩ resistors in series.

The lower leg is formed by the 820kΩ and 30kΩ resistors in series with trimpot VR1, with the 10MΩ input resistance of the DMM itself in parallel.

When the value of this composite lower leg is adjusted using trimpot VR1 to have a resistance of 1/999 of the input leg (ie, nominally 800MΩ/999, or 800.801kΩ), the divider provides an exact division ratio of 1000:1.

Trimpot VR1 allows you to compensate for the within-tolerance variations in all of the other resistors, to give the probe maximum accuracy.

So, while the circuit of the probe is very straightforward, the physical construction presented us with quite a challenge, in order to meet the somewhat conflicting needs of fitting

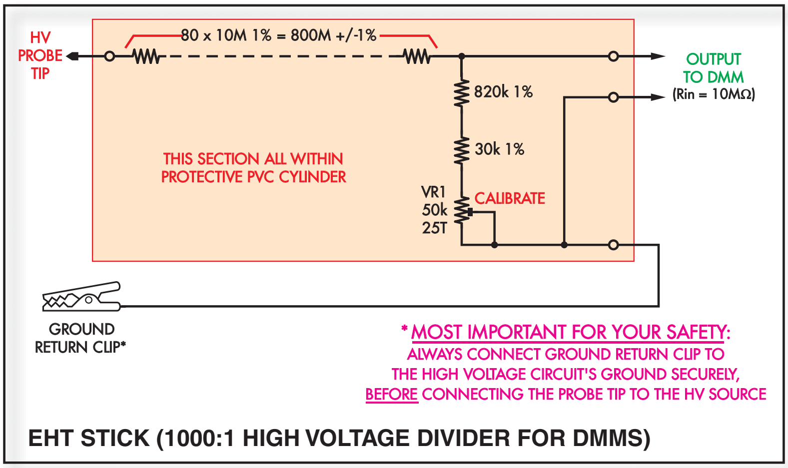
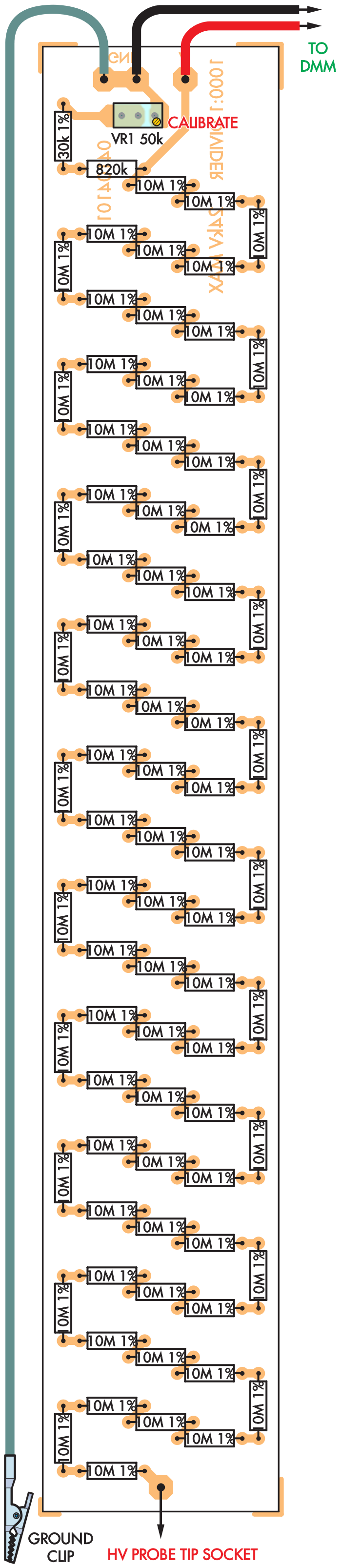


Fig.1 (above): the circuit is simply a voltage divider giving a suitable output to measure on a digital multimeter

Fig. 2 (right): shows the PC board component overlay. It's not difficult to build, but it is quite tedious fitting and soldering 82 half-watt resistors. Note: do not substitute other resistors as their voltage rating may be insufficient



no fewer than 82 0.5W resistors plus a trimpot into a case that would be compact enough to be handheld, yet provide a high level of electrical isolation and safety.

Construction

The approach to construction we came up with was to fit all of the resistors and the trimpot onto a long narrow PC board, measuring 228mm × 37mm. This board is available from the *EPE PCB Service*, code 841. The 80 resistors in the divider's input leg are laid out in a long 'zig-zag' pattern over most of the board's length, to provide the necessary spacing in a reasonably compact area.

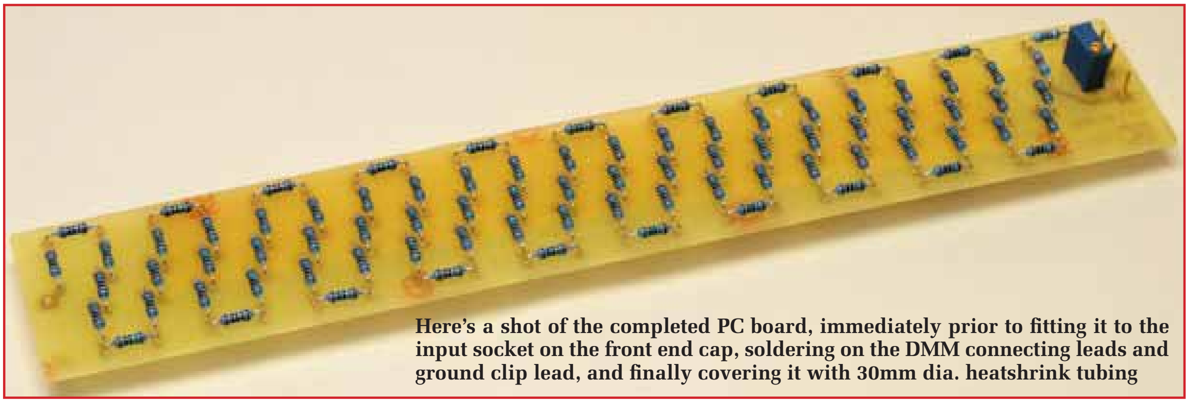
The PC board, sleeved in 30mm heatshrink tubing, is designed to fit inside a 250mm length of 43mm OD/39mm ID PVC-U conduit, with a 43mm ID PVC pipe cap at each end to complete the safety isolation.

The PVC-U conduit needs matching end caps, both can be obtained from hardware stores and plumbing supply outlets. Most vendors will supply minimum lengths of one metre, but a 1m length should only cost a couple of pounds. One of these days we're sure to come up with a use for the rest!

Parts List – EHT Stick

1 PC board, code 841, available from the *EPE PCB Service*, size 228mm × 37mm
1 250mm length of 43mm OD/39mm ID PVC-U conduit
2 43mm ID PVC pipe cap to suit conduit
1 230mm length of 30mm diameter heatshrink tubing
1 4mm banana socket, red with matching double-adaptor banana plug
1 3.5-6mm cable gland
2 1.2m long 600V-rated test leads (one red, one black) with shrouded banana plugs
1 1m length of mains-rated flexible earth lead, with green insulation
1 32mm (medium) alligator clip, with black or green insulating shroud
4 1mm diameter PC board terminal pins
1 nylon cable tie, 4mm wide
1 short (~50mm) length brass rod, around 2mm to 3mm diameter (for tip)

Resistors (0.5W 1% metal film)
80 10MΩ 1% Vishay BC (500mW rating – Farnell 1772424)
1 50kΩ 25-turn vertical trimpot (VR1) 1 820kΩ 1 30kΩ



Here's a shot of the completed PC board, immediately prior to fitting it to the input socket on the front end cap, soldering on the DMM connecting leads and ground clip lead, and finally covering it with 30mm dia. heatshrink tubing

Or you might also try your friendly local plumber for an offcut. The plumber might also be good for a short length of 4mm brass rod (eg, brazing rod) to fashion a probe tip.

The end caps are a (tight!) friction fit onto the conduit. This provides adequate physical security while maintaining good electrical isolation. We suggest you *don't* try to check the fit out before final assembly, because once on, they're not easy to get off again!

A 4mm banana socket is mounted in the centre of one end cap to provide the probe's 'hot' input, the idea being that whichever probe tip (or very short clip lead) you use plugs into the socket via a standard 4mm banana plug.

As we mentioned earlier, a short length of brass rod makes an excellent probe tip – we made ours from a piece of brazing rod about 50mm long (certainly not critical) with a point filed one end and soldered to a banana plug to mate with the banana socket.

A cable gland is mounted in the centre of the other end cap to provide an exit for the probe's output leads and its ground return input lead.

Board assembly

Wiring up the probe board is not difficult, but it is a little tedious because of the large number of resistors to be fitted. The easiest part is fitting the four PC board terminal pins used to make the off-board connections – one at the input end to mate with the solder lug at the rear of the banana socket, and the other three at the output end to provide the cable connections.

Note that the single pin at the input end should be fitted from the copper side, with its 'top end' cut off flush when you have soldered it to the copper pad underneath – see Fig.3.

Once the pins have been fitted, you can proceed with installing the fixed resistors. They're fitted in the standard way, with the leads bent down at 90° quite close to the resistor body so that when they pass through the board holes, the resistor is lying flat on the top of the board.

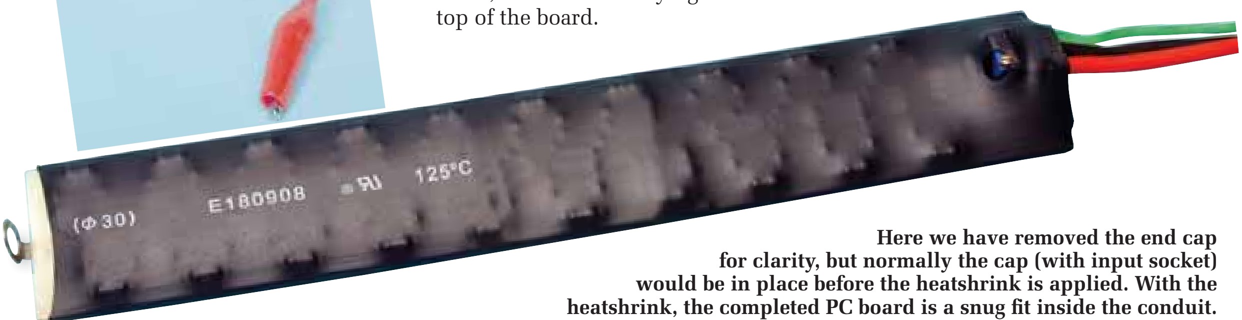
The leads are then soldered carefully to the pads underneath, with just enough solder used to produce a nicely rounded joint. The excess leads are then cut off with sharp side cutters as close as possible to the joints, so that no sharp wire ends or 'points' are left.

This is quite important, because any sharp points on conductors carrying high voltage tend to concentrate the surrounding electric field and cause ionisation of the air – producing a 'corona' discharge.

The only other thing to watch when you're fitting the resistors is to fit the 820kΩ and 30kΩ resistors down at the output end of the board, as shown in the overlay diagram (Fig.2).

You might want to fit these first, to make sure they're in the correct positions. Then, you can fit the remaining 80 resistors, happy in the knowledge that they are all of the same value.

With all of the fixed resistors installed, the only remaining step is to fit trimpot VR1 and your probe's PC board assembly will be complete. It can then be put aside while you prepare the probe's tube and end caps, and then assemble the whole thing.



Here we have removed the end cap for clarity, but normally the cap (with input socket) would be in place before the heatshrink is applied. With the heatshrink, the completed PC board is a snug fit inside the conduit. Inset top left is the 'probe' in its banana plug, here with optional crocodile clip connector.

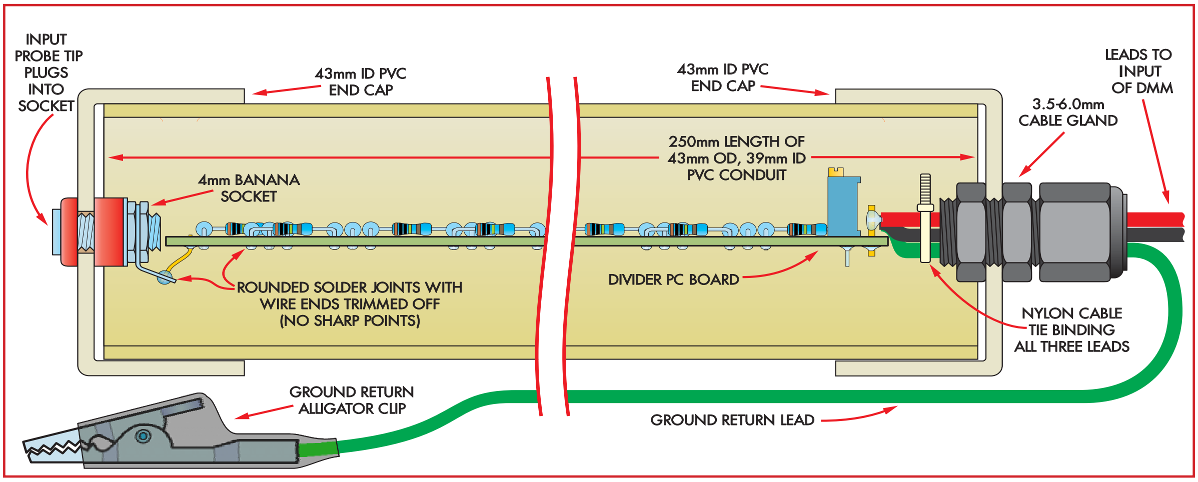


Fig.3: this shows how the completed project goes together. The only thing not shown here (again, for clarity) is the heatshrink tubing over the PC board. This provides extra electrical insulation

Final assembly

Final assembly also involves calibration. This could be done now that the PC board is complete, but it's better to wait until the unit is partly assembled (and therefore partly insulated) as it involves high voltages.

First cut your length of 43mm OD PVC-U conduit to 250mm long. If necessary, square off each end with a flat file, using it to remove any burrs as well.

Next, drill the holes in the centre of each end cap to receive the 'hot input' banana socket and the output cable gland. These both need round holes of around 9mm diameter, but the exact diameter will depend on the particular components you use – and the holes shouldn't be any larger than is necessary to receive them.

So, it's probably best to drill a 5mm (approx) hole in each cap first, and then use a tapered reamer to enlarge it carefully until the socket or gland will just pass through. Then remove any burrs as before.

Mount the input banana socket securely in its end cap, using one of the two nuts supplied to fasten it in position. Next, fit the solder lug and the second nut, tightening this up so that the lug is securely attached to the back of the socket. Then bend the lug over against the side of the second nut. This will bring it into position where its end hole will be as near as possible to the input terminal pin on the end of the divider probe's PC board, when assembled. The bent lug will also help to hold the nut in position.

Now slide the PC board into the end cap so that the solder lug on the banana socket and the PC board input pin can mate. This is a little tricky, but if you keep the solder lug and PC board parallel to each other, you should have success.

Once the pin does pass through the hole in the solder lug, you can solder the two together carefully to make the connection permanent.

Make sure that you apply enough solder to form a strong and nicely rounded joint – also take care not to burn the side of the PVC end cap with the barrel of the soldering iron. Your end cap and PC board assembly should now look very much like the photo below right.

Putting it together

Loosely fit the cable gland to the other end cap and pass the bare ends of the three exterior wires (ie, the two leads which go to the DMM and the ground lead) through the gland from outside to inside. Pull these three wires through as far as they will go so that the DMM plugs and ground clip lead are against the cable gland.

If necessary, cut the 30mm diameter heatshrink tubing to length (~230mm, give or take) and either cut or drill a pot access hole. We placed a scrap of timber inside the heatshrink and drilled a 6mm hole, right in the centre and 10mm down from the end.

Pass the three external wires right through the heatshrink, from the pot access-hole end, all the way along the wires (you want to keep the heatshrink away from the heat of soldering in the next step).

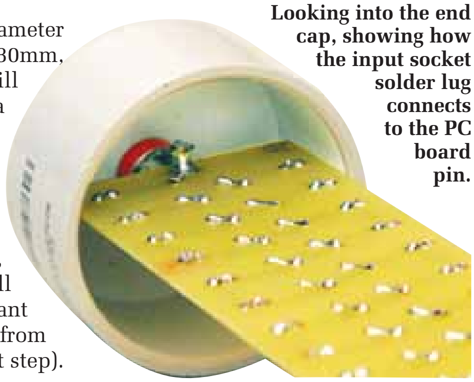
Similarly, pass the three external wires through the PVC-U pipe and slide the pipe up the wire. Don't push the end cap onto the pipe, at least not yet!

Now solder the three external wires to their appropriate positions on the PC board, as shown on overlay Fig.2. Fit a small nylon cable tie around the three wires to keep them together, but not so close to the PC board that it causes undue strain on the wires.

The final step before calibration is to slide the heatshrink back down the three wires and all the way onto the PC board, locating the pot access hole over the pot and then shrinking the heatshrink onto the PC board. A hot air gun is best, but a hair drier on a high heat setting will work – it just takes a bit longer.

Calibration

Before completing the probe, now is the time to adjust trimpot VR1 for a division ratio of exactly 1000:1 – in other words, calibration.



Looking into the end cap, showing how the input socket solder lug connects to the PC board pin.

Ideally, you'll need a convenient source of stable medium-high voltage to do this (say 750V to 950V DC).

If you don't have such a source, your best plan would be to simply set VR1 to around the middle of its range, using one of your DMM's resistance ranges to do this. Simply connect the DMM leads directly across VR1, and turn its adjustment screw with a small screwdriver until you get a reading of close to 25kΩ. This should give your probe a division ratio within about 3% of the correct figure.

If you do have a source of stable high voltage, calibrating the probe is quite simple. You just need to be extra careful, because high voltage can 'bite'!

Having a banana socket with removable tip also makes it easier (and safer) to connect to your high voltage, as exposed metal is kept to a minimum.

You'll also need to connect the board's ground return lead pin (at the output end of the board) to the negative side of your high voltage source securely, *before* you start.

Measure and note down the voltage using your DMM directly, set to its top DC voltage range. Remove the DMM leads from the DC voltage source and connect instead the output leads from the probe board.

Then connect the probe's input socket to the positive side of the high voltage source, and you should be able to read the probe's output voltage on the DMM. It should be very close to 1/1000th of the first reading and all you now have to do is adjust VR1 with a small screwdriver until it becomes as close as possible.

To end this procedure, disconnect the probe tip from the positive side of the high voltage source, then disconnect the temporary ground return lead from the negative side and finally disconnect it from the ground lead pin in the rear of the probe PC board. Your EHT Stick should now be calibrated, and ready for final assembly.

Give everything the once-over again, just in case – remember that once the end caps go on, they're rather difficult to get off again!

In fact, it's a good idea to loosely place the end caps as you follow the next steps and then make some trial measurements, just to make sure everything is still working.

It's complete!

Slide the pipe back down the wires and over the heatshrink-covered PC board. It's a snug fit but it does go in.

Place the front end cap onto the pipe and slide the other end cap right back down the wires to the cable tie.

Leaving a small amount of slack inside the pipe, tighten the cable gland and then push the rear end cap loosely onto the pipe.

If your test measurements look satisfactory, push both end caps hard onto the pipe. No screws (or glue) are necessary to hold the caps in place – they won't come off by themselves! *EPE*

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Last month, we described how the S/PDIF Digital Audio Signal Generator works. This month, we describe how to assemble the PC boards, mount them in the case and check that they are working correctly.

By NICHOLAS VINEN

High-Quality Digital Audio Signal Generator – Part 2

THE *Digital Audio Signal Generator* is built on two PC boards: a main board and a control/display board. Construction can begin with the assembly of the main PC board. There are two versions, one to suit the Jaycar case (Fig.10) and the other to suit the Altronics case (Fig.11). The Jaycar main board is coded 838 (Jay) while the Altronics board is coded 838 (Alt).

These boards, together with the control/display board, are available from the *EPE PCB Service* as a pair. You do need to specify which Main PC board you require; according to which type of case you shall be using – ie, Jaycar HB-218 or Altronics H-0330 (see text).

Before starting, examine the copper side of the PC board for any defects. It's also a good idea to place it inside the case, up against the end, in order to check that it fits properly. Verify that the mounting holes line up with the posts in the base of the enclosure.

Main board assembly

Once you are satisfied that it will fit, start the main board assembly by installing the seven wire links. You can use 0Ω resistors for the shorter links and 0.71mm tinned copper wire for the longer ones (or you can use tinned copper wire for the lot).

Next, install the 0.25W resistors. It's best to check the value of each with a DMM before installation, as the colour codes can be hard to read.

Follow these with the four diodes (D1 to D4) and Zener diode ZD1. Pay careful attention to the orientation of these parts. You will have to bend the leads of the 1N5819s close to their bodies for them to fit.

The five IC sockets can now be installed. Be sure to line the notches/indent dot up with those shown on the overlay. Solder two diagonally opposite pins on each IC holder, then check that they are sitting flat on the PC board before soldering the rest.

Crystals X1 and X2 are next on the list. Be careful not to get them mixed up. The markings on their cases should match the corresponding frequency values on the PC board overlay – Fig.10/Fig.11.

Once these are in place, you can install the 10Ω 1W resistor (see panel). If you install it, you can *only* use rechargeable cells or the plugpack to

power the device – you cannot use alkaline or other non-rechargeable batteries. **If you do want to use alkaline batteries (or the plugpack), then leave this resistor out.**

Since the physical size of this resistor can vary, you will need to make sure that it doesn't interfere with the battery connector. If necessary, install it slightly proud of the PC board so that it sits above the adjacent 1N5819 diode (D2).

Next, the two TO-220 voltage regulators (REG1 and REG2) can be installed; take care not to get them mixed up. In each case, bend the leads down through 90° about 5mm from the body using a pair of needle-nose pliers. That done, mount the device on the board, line up the metal tab mounting hole and secure it using an M3 × 6mm machine screw, nut and star washer (the latter goes under the head of the bolt).

Finally, solder the pins to their respective pads and trim away the excess. Do not solder the pins before you have bolted the devices down, otherwise you could crack the copper tracks as the screw is tightened.

The next step is to install the IDC (insulation displacement connector) socket (CON4). It should be installed with its notched side towards the bottom (see Fig.10/Fig.11 layout diagrams). Solder pin 1 and pin 16 first, and make sure the socket is sitting flush against the board before soldering the rest.

Installing the transistors

Transistors Q1 to Q7 can now be fitted. These all come in TO-92 plastic packages, but there are three different types, so read the markings carefully.

In some cases, the leads may be too close together to fit through the mounting holes. If so, use needle nose pliers to bend the two outer legs apart to 45°, close to where they emerge from the case, and then back parallel again further down, so that they will fit in place.

The three polarised header connectors (CON1 to CON3) go in near the bottom edge of the board. Be sure to orient them as shown (Fig.10/11), and make sure they are sitting flat against the board before soldering their pins.

Now fit the capacitors, starting with the MKT and ceramic types. These can go in either way around. Once these are all in, install the electrolytics. Their orientation does matter, so make sure they go in the right way around.

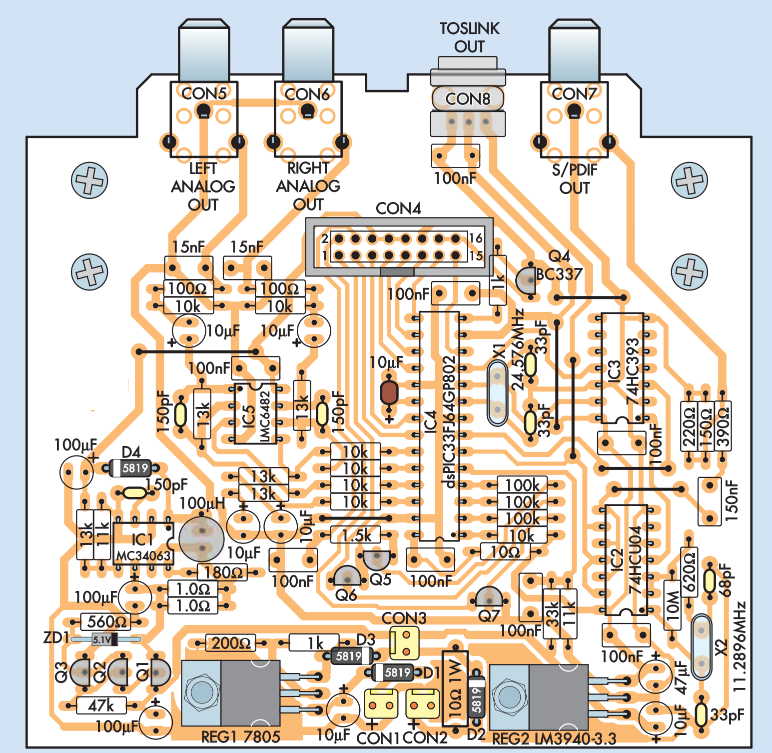


Fig.10: follow this diagram to build the main PC board for the Jaycar case. Make sure that all polarised parts are correctly oriented and install the 10Ω 1W resistor only if you intend using rechargeable cells (see panel).

Be extra careful with the tantalum capacitor, which is also an electrolytic, but uses a different electrode material. It's easily destroyed by reverse polarity. The only reliable way to check the orientation is to look for the '+' sign printed on the epoxy case, above one of the legs.

The main board assembly can now be completed by installing the 100μH inductor, the TOSLINK transmitter and the three RCA phono sockets. When mounting the TOSLINK transmitter, push its two plastic posts down through the holes in the board until they snap in, then check that it is sitting flat and parallel with the edge of the PC board before soldering its pins.

Be sure to use a white RCA phono socket for the left analogue output, red for the right analogue output and black

Choosing the trickle charge resistor

As mentioned in Part 1, nickel metal hydride (NiMH) rechargeable cells can be used to power the unit and the circuit includes a 10Ω 1W resistor to trickle charge them whenever the plugpack is connected. This resistor value is suitable for 2000mAh cells, and provides just under 100mA to the cells once they are fully charged

This equates to a charge rate of C/20 for 2000mAh cells, although it will be appreciably higher than this when the cells are flat.

If you use lower capacity cells, then you need to increase the value of the resistor accordingly. For example, 800mAh cells require a 27Ω 1W resistor, while 600mAh cells require a 33Ω 1W resistor.

Note that you should install this resistor only if you intend using NiMH or Nicad cells in the device. Do not install it if you intend using alkaline (or any other non-rechargeable) cells.

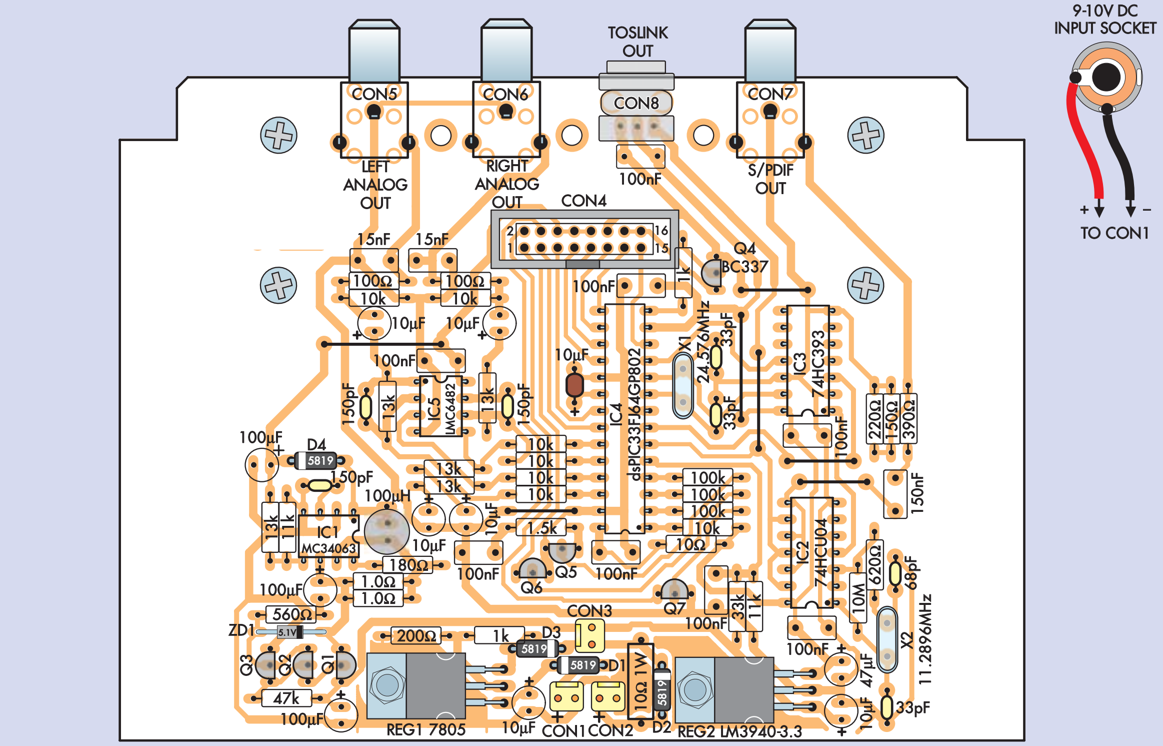


Fig.11: this is the alternative main board layout to suit the Altronics case. The circuit layout is almost identical to the Jaycar version, but the mounting holes and output sockets are in slightly different locations. The diagram at top right shows how to wire the DC socket (both versions).

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	10MΩ	brown black blue brown	brown black black green brown
❏	3	100kΩ	brown black yellow brown	brown black black orange brown
❏	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❏	2	33kΩ	orange orange orange brown	orange orange black red brown
❏	4	13kΩ	brown orange orange brown	brown orange black red brown
❏	2	11kΩ	brown brown orange brown	brown brown black red brown
❏	7	10kΩ	brown black orange brown	brown black black red brown
❏	1	1.5kΩ	brown green red brown	brown green black brown brown
❏	2	1kΩ	brown black red brown	brown black black brown brown
❏	1	620Ω	blue red brown brown	blue red black black brown
❏	1	560Ω	green blue brown brown	green blue black black brown
❏	1	390Ω	orange white brown brown	orange white black black brown
❏	1	220Ω	red red brown brown	red red black black brown
❏	1	200Ω	red black brown brown	red black black black brown
❏	1	180Ω	brown grey brown brown	brown grey black black brown
❏	1	150Ω	brown green brown brown	brown green black black brown
❏	2	100Ω	brown black brown brown	brown black black black brown
❏	1	10Ω	brown black black brown	brown black black gold brown
❏	1	5.6Ω	green blue gold brown	green blue black silver brown
❏	2	1Ω	brown black gold gold	brown black black silver brown

for the S/PDIF output. You may have to press the sockets down hard into the board to get their plastic posts to sit properly. Note that they do not go all the way down through the board, but rather sit in the holes.

Ensure that the phono socket bases are sitting parallel with the PC board before soldering them in place. It is best to check them from the perspective of the sides and end of the PC board, as they can be mounted askew in either plane.

That completes the main PB board assembly, but leave the ICs out of their sockets for the time being.

Building the control board

The component layout for the control PC board is shown in Fig.12. Start assembly by installing the seven 1N4148 small signal diodes (D5 to D11). They all face in the same direction. That done, install the IDC socket (CON 9) with the orientation shown, then install the 5.6Ω resistor and the single 100nF MKT capacitor.

The way in which the LCD module is mounted depends on which case you are using. Don't remove the protective plastic from the top of the LCD yet.

(1) Jaycar case: if you are using the Jaycar case, begin by fitting M3 × 6mm machine screws through the holes on the control board (ie, either side of the LCD position), with the head on the copper side. Next, thread an M3 nut onto each screw until it is tight and screw an M3 × 9mm tapped nylon spacer down on top.

The LCD module connects to the PC board via male and female 16-pin headers. For the time being, just loosely insert the long pins of the male header into the female header.

(2) Altronics case: for the Altronics case, first fit an M3 × 6mm screw through the holes on either side of the LCD position (head on the copper side), then screw on an M3 × 9mm nylon spacer (ie, no nut). That done, use a pair of pliers to pull the pins out of the plastic spacer of the male pin header. These must then be fully inserted, one at a time, into the holes of the female header.

When you are finished, you can discard the leftover plastic spacer.

Mounting the LCD

You are now ready to mount the LCD module. Begin by placing the female header's pins into the row of 16 holes on the PC board, then sit the LCD on top. The upwards-facing pins should fit into the corresponding row of holes on the LCD board. You then secure the LCD module using M3 x 6mm machine screws, which go through the LCD module and into the nylon spacers.

It's now just a matter of soldering the pins on the underside of the control board and on the top of the LCD module. There are 32 in all, so don't miss any and be careful to avoid shorts between them.

This is the view inside the Jaycar case after the main board, power switch (top right), DC socket (top left) and cell holders have been installed. The cell holders are connected in series.

Pushbutton switches

Now that the LCD is in position, it's time to install the seven tactile switch buttons. Their bases are rectangular, so you can't install them the wrong way.

To install each switch, first insert its angled pins through the board holes and push it down so that it sits flat against the PC board. Check that the switch shaft is as close to vertical as possible, then solder all four pins. Be careful that the buttons don't move when you turn the assembly over to solder them.

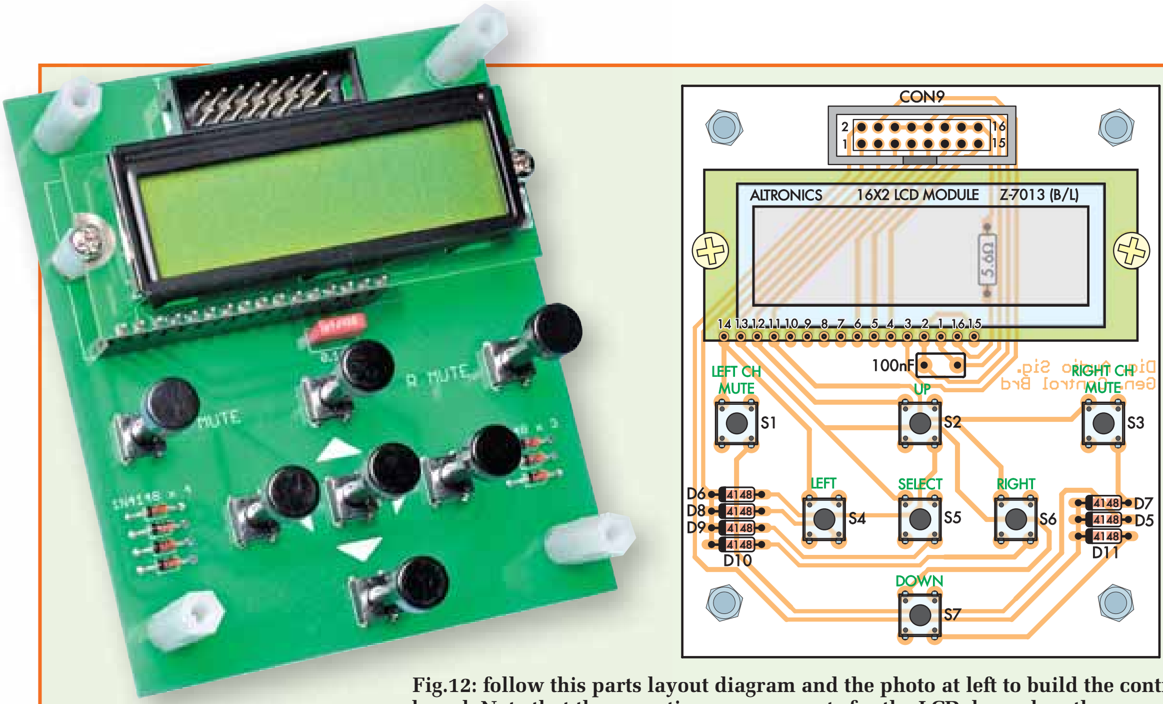


Fig.12: follow this parts layout diagram and the photo at left to build the control board. Note that the mounting arrangements for the LCD depend on the case you will be using – see text.

Completing the control board

Having fitted the switches, the control board can be completed by fitting its mounting screws and spacers.

Begin by inserting an M3 × 15mm machine screw through each of the four corner mounting holes (with the head on the copper side), then thread an M3 × 9mm tapped nylon spacer over each screw and tighten it down. When that's done, each screw should protrude about 4mm beyond its spacer.

The next step depends on the case you are using. If you have the Jaycar case, simply screw an M3 x 12mm nylon spacer down over each exposed screw. Alternatively, for the Altronics case, fit two M3 star washers over each screw, then screw down another M3 × 9mm tapped nylon spacer on top.

When you have finished this step, the spacer ends should be slightly above the level of the LCD. You can now remove the protective plastic coating from the LCD, and place the control board to one side while you run some basic tests.

Testing the main board

It's a good idea to test the main board before going any further. You can either use a bench power supply (set at 9.5V, with a current limit of 150mA) or a 7.5V to 10V DC plugpack with an ammeter in series.

If you are going to use an unregulated plugpack, 7.5V may be the best choice because it will deliver a higher voltage due to the relatively light load – probably at least 9V. Check with a voltmeter if you are unsure. If the no-load voltage output is above 9V and the current rating is at least 500mA, then it should be fine.

Place a shorting link (or 'jumper') across the switch pin header (without it, the circuit will not turn on). Also, make sure none of the ICs are installed in their sockets.

Next, apply power via the external DC header (CON1) – not the battery header – and observe the current reading. It should be less than 10mA.

If that checks out, measure the voltage at the output of each TO-220 regulator using your DMM. In each case, place the black probe on pin 2 or the tab, and the red probe on pin 3. You should get readings of 6.8V ± 10% for REG1 and 3.3V ±5% for REG2.

If any reading is wrong, switch off immediately and check that all parts have been installed correctly.

Now measure the voltage between pin 6 and pin 4 of the socket for IC1 (MC34063). It should be close to 5.0V. If it is below 4.7V or above 5.2V, then check the voltage across Zener ZD1.

Because low-voltage Zener diodes have a relatively high impedance, you will find it is well below its rated voltage of 5.1V. We want it to be around 4.3V. If yours does not read between 4.0V and 4.5V, then that will be the reason for IC1's voltage reading being out of range. In that case, you will need to try a different Zener diode with a different voltage rating, or try one from a different manufacturer.

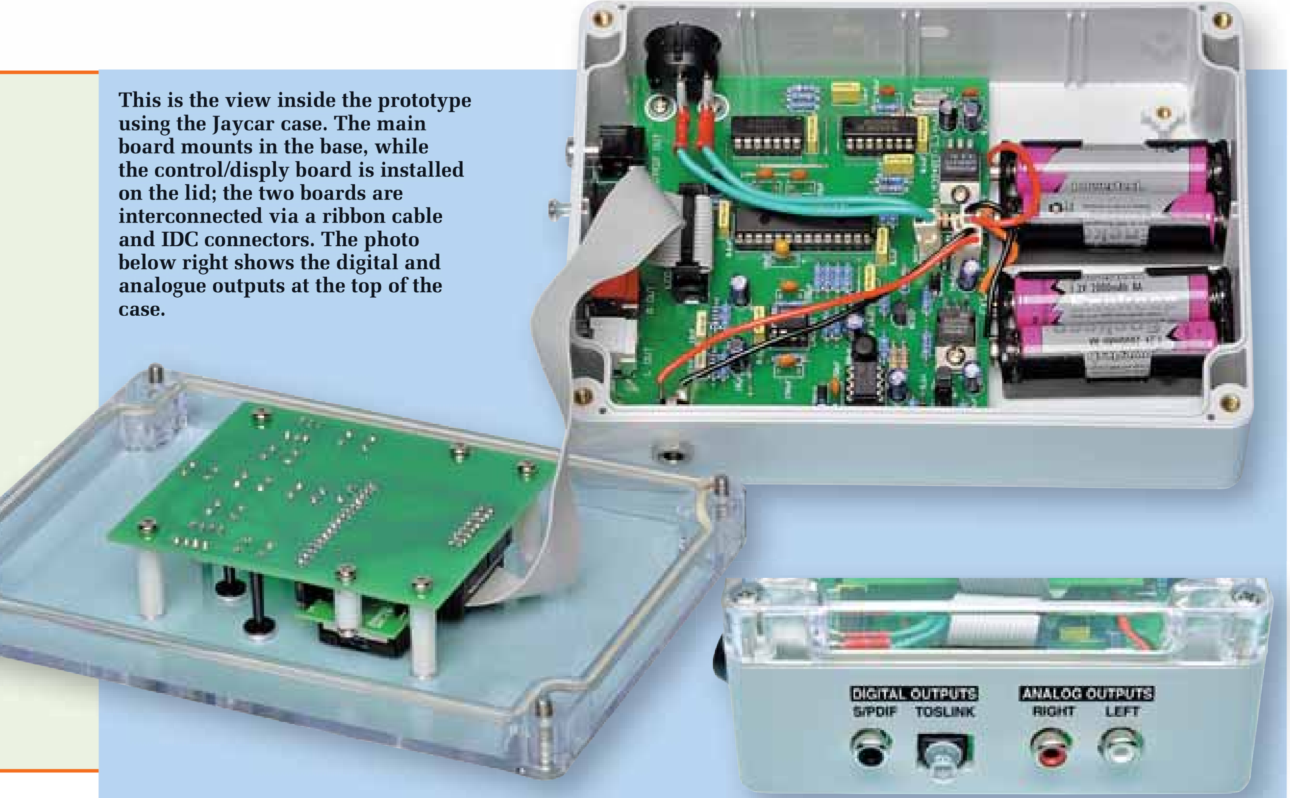
The most likely types to be suitable are 4.7V and 5.1V Zeners, but unfortunately there is no easy way to tell without measuring it.

Once the supply voltage is within the acceptable range, turn the power off and install IC1 (MC34063), ensuring its orientation matches the socket. If you are using a bench supply, set it to 7.0V, reapply power and again check that the current is less than 10mA.

Now measure the voltage between pin 8 and pin 4 of IC5's socket. It should be 5.0V ± 5%. If not, there is a problem with the MC34063 IC or the surrounding components.

Turn the power off again and install IC4 (dsPIC33). Make sure it has been programmed with the appropriate software, and that it is installed with

This is the view inside the prototype using the Jaycar case. The main board mounts in the base, while the control/disply board is installed on the lid; the two boards are interconnected via a ribbon cable and IDC connectors. The photo below right shows the digital and analogue outputs at the top of the case.



the correct orientation. Also, install the three remaining ICs – IC2, IC3 and IC5. Don't get the 74HC04 and 74HC393 ICs mixed up – they have the same number of pins.

Reapply power and check that the current is below 150mA. In fact, it should be close to 100mA. If you have a frequency counter, measure the frequency at pin 6 and pin 8 of IC3 (74HC393) relative to pin 7 (ground). Pin 6 should read 705.6kHz and pin 8 should read 1.536MHz. If not, check the crystal oscillators and the circuitry surrounding IC3 for mistakes.

If the pin 6 reading is correct, but the pin 8 reading is not, there could be a problem with IC4's (dsPIC33) oscillator circuit. Check its power supply.

Testing the outputs

The next step is to test the analogue outputs. When powered up for the first time, both channels should output a full scale (1V RMS) 1kHz sinewave after a couple of seconds.

You can test them by connecting them to an oscilloscope or to an audio amplifier. If you use an amplifier, make sure its volume is turned well down before applying power to the signal generator. If they do not work properly, check the circuitry around IC5 (LMC6482).

To test the digital outputs (S/PDIF and TOSLINK), connect them to a DAC or to an amplifier with digital inputs, again being careful with the volume. If neither output works, the dsPIC33 may not be programmed correctly, or it may not be functioning due to incorrect parts placement or an incorrect power supply.

Testing the control board

Now that the main board is working, it is time to connect the control board. First, you will need to make up an interconnecting ribbon cable. One option is to use an IDC crimping tool (such as the Jaycar TH1941 or Altronics T1540), but if you do not have one, a vice can do the job of squeezing the two sections together.

One 16-pin IDC connector should be attached to each end of the ribbon cable, on opposite sides and with the plastic tabs facing out from the middle, as shown in Fig.13.

Don't forget to feed the cable through the top of the connector first before looping it around to the blades below.

Once you have made the cable, it's a good idea to plug it into both boards and use a DMM set to continuity mode to check that all the corresponding pins on the two PC boards are electrically connected. If you haven't crimped the cable with sufficient force, some of the blades may not pierce the insulation properly and those wires will read as open circuit.

If any lines are open circuit, you will need to crimp the connectors harder, or make up a new cable.

Switch-on

Once you are sure that the cable is OK, leave it connected to both boards and reapply power. If you are using a bench supply, you should increase the current limit setting to 300mA, as the LCD backlight will draw additional current.

As soon as power is applied, the LCD backlight should turn on and some text should be visible. The current should be in the range 120mA to 150mA. Initially, the display contrast will probably be too high, that's because we've erred

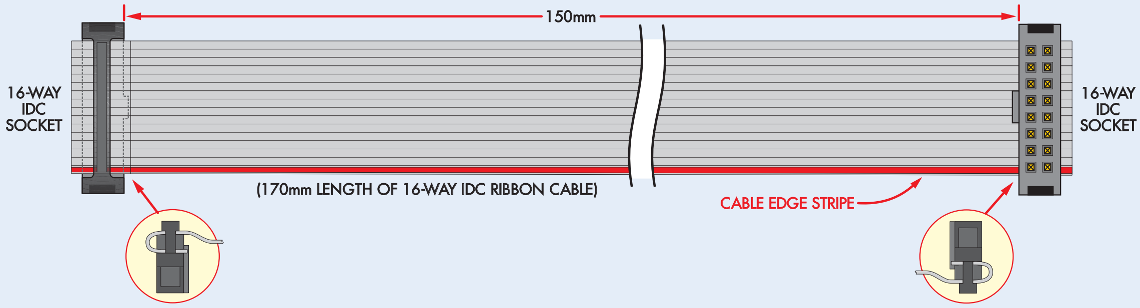


Fig.13: here's how to make up the IDC header cable that connects the two PC boards. Be sure to orient the header sockets exactly as shown. You should also leave about 15mm free at each end so that the cable can be looped back and clamped with the locking bar.

on the side of caution to cater for any variations between the panels.

If you don't see anything on the display, check the cable continuity again, as well as the components and solder joints on the control board. It's also worth checking the components in the contrast control circuitry on the main board (ie, the circuitry associated with transistor Q5). If all the hardware seems OK, then you may have a faulty microcontroller or LCD module.

Once it is working, try pressing the 'Up', 'Down' and 'Select' buttons and check that the display changes each time you do. Now turn the power off and then on again, and try the 'Left' and 'Right' buttons. You should see a cursor appear on the display that you can move around.

Finally, press the 'Left Mute' and 'Right Mute' buttons, and check that the display changes when you do. If your boards pass all these tests, they are working properly.

Adjustments and calibration

There are a few tweaks that have to be made before the unit is installed in its case. However, be extra careful not to let the bottom of the control board short against the main board while you do this.

First, you should adjust the LCD contrast to its optimum setting. To do this, turn the unit off and then on again, then press the following sequence of buttons: Select, Up, Up, Left. The display will show the current brightness and contrast settings, and you can now use the Up and Down buttons to adjust the contrast.

Once you have found a good setting, press Select, Up, Right. The display will now read '3.3V Cal.: 3.300V'. When it does, carefully measure the output of the 3.3V regulator (REG2) – ie, black probe on pin 2 or the tab, and the red probe on pin 3.

Once you have taken the reading, use the Left/Right buttons to move the cursor and the Up/Down buttons to change the digits on the display until it is as close as possible to the measured voltage.

Finally, press: Select, Down, Down, Left, Up. The display should read 'Saved', indicating that the settings have been saved to the dsPIC33's Flash memory.

Performing this calibration routine maximises the accuracy of the microcontroller's ADC readings, as they are measured relative to the 3.3V supply voltage. Once calibration is complete, remove the shorting jumper from the switch header.

Preparing the case

The main PC board is designed to fit into a sealed polycarbonate enclosure with a transparent lid – either the Jaycar HB-6218 (171 × 121 × 55mm) or the Altronics H-0330 (186 × 146 × 75mm)

In each case, the transparent lid saves you the effort of having to cut a neat rectangular hole for the LCD to be visible. These polycarbonate enclosures are also quite sturdy.

The main board mounts on posts which are moulded into the bottom of the box. It is necessary to drill or cut holes for the outputs (three for the RCA sockets and one for the TOSLINK transmitter), a hole for the power switch and one for the DC connector.

If you are building the project from a kit, then it's likely that the case will be supplied pre-drilled. If not, then you will have to drill the holes yourself.

Fig.14 shows the drilling details for the Jaycar case and this can be photocopied and used as a drilling template.

Once the template is in place, it is a good idea to temporarily place the main board inside the box and check that the sockets line up correctly with the indicated hole positions. When you are sure it is correct, remove the PC board and drill a small pilot hole in the centre of each RCA phono socket position. Also drill a small hole inside each corner of the TOSLINK connector outline (make sure that these do not go outside its outline).

By the way, there is a simple way to accurately drill holes in the plastic. At each location where you want to drill a hole, press the sharp point of a hobby knife there and rotate it several times, until you have made a small divot in the plastic. This will guide the drill bit and prevent if from slipping. Even if you are using a drill press, this simple technique will help to initially guide the bit.

Having drilled the pilot holes, remove the template and place the PC board back inside the box. Slide it up against the pilot holes and check that they are correctly aligned. You can do this by inserting a piece of wire into each hole and checking that it passes through the centre of the corresponding socket.

If any holes are misaligned, then now is the time to correct the situation.

When they are correctly lined up, use a stepped drill bit or a series of increasingly larger bits to enlarge the phono socket holes. A tapered reamer can then be used to get the size just right (about 10mm).

Making the cutout

The rectangular cutout for the TOSLINK transmitter is made by first drilling a series of small holes around the *inside* perimeter, using the four corner holes you drilled earlier as a guide. It's then just a matter of knocking out the centre piece and filing the job to a smooth finish.

During this process, you can test fit the PC board to determine which sides need further filing. Continue this process until the connector is a neat fit.

Note that because of the thickness of the box, we've had to put the TOSLINK connector closer to the edge of the PC board than it is supposed to be. This means that the wider rear portion has to fit through the cut-out too. So, if it looks like it should fit but it won't go all the way in, it is probably the larger rear portion which is getting stuck.

When you are finished, the PC board should slide right up against the end of the case and the mounting holes on the board should line up with the posts. The TOSLINK transmitter face should sit flush (or nearly so) with the outside wall of the case.

Power switch and socket

Before finally installing the main board, you also have to drill the holes for the power switch and DC socket. The recommended switch type is a 20mm round rocker type, but you can use a different type if you like (eg, a sub-miniature toggle switch, as used in our second prototype).

The main thing to keep in mind is that the internal portion of the switch needs to clear the main PC board and its components. In the Jaycar case, that's done by mounting the switch on the side, between the PC board mounting holes.

The DC power socket is mounted on the side opposite to the power switch (see photos).

Once you have marked their positions, remove the PC board and drill two pilot holes. That done, enlarge the holes to the correct sizes using a tapered reamer – 20mm for the rocker switch and 7.5mm for the DC socket.

If you use the same switch we did, it will also be necessary to file a small notch in the top of the mounting hole. This is because the switch has a tab to stop it rotating. It doesn't take long to file away enough material and when

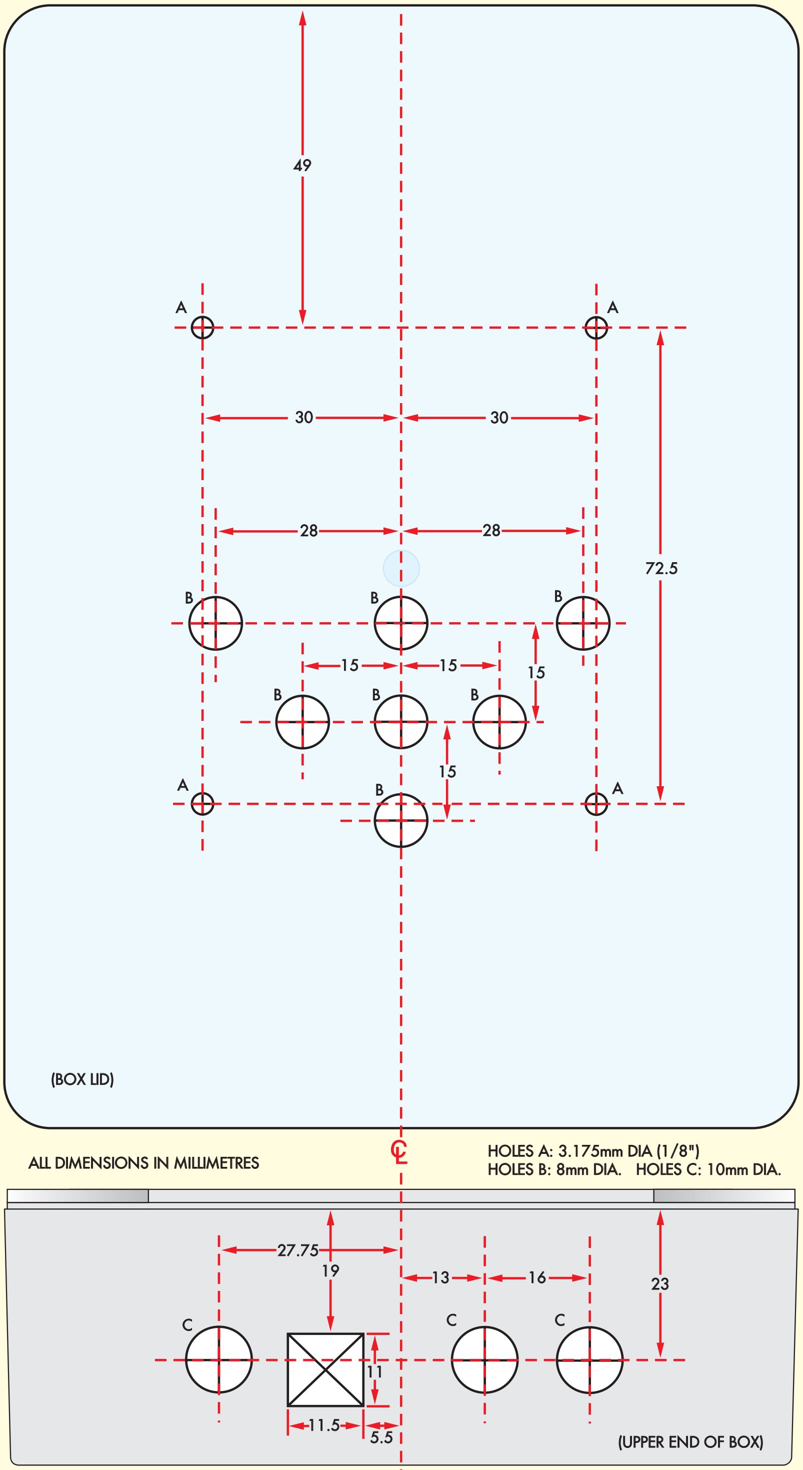


Fig.14: this diagram shows the drilling details for the Jaycar case. The diagram can be photocopied and attached to the case and used as a drilling template.

This second prototype of the Digital Audio Signal Generator has been built into the Altronics case.

you are finished, the switch should snap into the panel.

Alternatively, for the Altronics case, the switch and DC socket are mounted on the end panel, on either side of the output sockets. – see photo on page 27.

Installing the main board

It is now time to slide the main PC board into place and secure it using four M3 × 6mm machine screws. If necessary, temporarily remove the power switch to do this, then reinstall it once the board is bolted down.

With the Jaycar case, two of the posts are pre-tapped with metal inserts, but the other two are not tapped at all. It takes a large driver and a great deal of force to force an M3 machine screw into these untapped posts (as we did), so you may prefer to use two small self-tapping screws instead.

The Altronics case comes with four self-tapping screws to suit its untapped posts. We've provided extra holes in the PC board for the additional posts even though four are enough to hold the board rigidly in place.

Drilling the lid

Fig.14 also shows the drilling details for the transparent lid (Jaycar version). There are 11 holes in all – four to mount the control board and seven for the pushbutton switches. The mounting holes (marked 'A') are all 3mm in diameter, while the switch holes ('B') are 8mm diameter.

As before, you should first attach the template and then use a sharp scriber or hobby knife to mark the centre of each hole. The template can then be removed and small pilot holes (say 1.5mm) drilled. It's then just a matter of enlarging the mounting holes to 3mm, while the switch holes should be carefully enlarged to 8mm using a series of slightly larger drill bits.

If you prefer, you can use M3 × 10mm countersunk screws to attach the control board to the lid. If so, you will need to countersink the mounting holes. Alternatively, you can use ordinary pan-head bolts.

Installing the control board

To install the control board, first press a button cap down over the end of each switch shaft. Make sure that they are all firmly attached, although full engagement is easiest once the board is in place.

You should also attach the ribbon cable to the control board at this point, since it's almost impossible to do it once the board is bolted to the lid. Leave the other end unplugged for now.

Once that's done, it's just a matter of fitting the control board into place and securing it using four M3 × 10mm machine screws. Note that it may be necessary to slightly loosen the mounting spacers on the board to get them to line up with the mounting holes. They can then be re-tightened once the mounting screws are installed.

When the board is secured in place, press down firmly on each button cap to ensure it is fully engaged with its switch shaft. When that is done, they should protrude through the lid by 1mm or so.

Battery holder

The signal generator is designed to run from a plugpack or from four 1.5V cells, typically alkaline or NiMH. We used ultra-low self-discharge NiMH cells in our prototypes, so that they don't go flat if the device is not used for some time.

Note that if you elect to use alkaline cells, then the 1W charging resistor *must not* be installed on the main PC board (see panel).

Unfortunately, side-by-side 4 × AA-cell holders are not easy to obtain, although 4 × AAA-cell holders are common. Of course, you can use AAA cells, but battery life will be less than half that of AAs.

The best approach is to use a pair of side-by-side double AA-cell holders wired in series. These can be secured to the base of the box using two strips of double-sided tape each, or they can be secured using countersink screws.

It's best to attach the leads before installing the holders. Attach a red wire to the positive terminal and a black wire to the negative terminal. If you are joining multiple holders in series, do that now.

Once everything is in place, connect the leads from the holders to the main PC board, as shown in the photographs. If you are using the 2-pin polarised headers, it's best to crimp and then lightly solder the wires to the connector pins before pushing them into the plastic block.

There is slightly more room for the battery holder in the Altronics box, so we used a 4 × AA holder with an integrated switch and lid. We did not install the lid because it would complicate access to the batteries should they require removal.

Note that because the switch is on the opposite side to the lid, it was necessary to use thicker foam-cored double-sided tape to attach it. The holder has integrated leads, so it is only necessary to attach them to the header connector before plugging it in.

The Altronics version has the power switch and DC power socket mounted at one end of the case, along with the analogue and digital output sockets.

Wiring the DC socket

We have specified a 2.1mm DC socket because this is the most common type for plugpacks. However, a 2.5mm type is also available if that's what your plugpack's connector requires.

The polarity of a DC connector isn't always obvious, so it's best to check the plugpack itself using a DMM. To do this, connect the plugpack to the mains and then place the DMM's red probe into the hole on the connector and touch the black probe to the outer metal ring. If you get a positive voltage, then your plugpack is centre (tip) positive; otherwise, it is centre negative.

For a centre-positive plugpack, connect the leads to the DC socket as shown on Fig.11, ie, red lead to the centre pin's solder tab and the black lead to the adjacent tab. Conversely, for a centre-negative plugpack, reverse the red and black wires.

Once you've soldered the leads to the DC socket, the free ends can be terminated in another 2-pin polarised header. Be sure to make the leads long enough to reach CON1.

Power switch

Almost any type of on/off switch can be used. The recommended switch is an SPST type, but it doesn't matter if it is DPST or DPDT. Note that because the switch goes after the 7805 regulator on the main board, a small amount of power (at least 3mA) will be drawn from the plugpack, even if the generator is switched off. This is so that the battery can trickle charge if you are not using the unit.

If your switch has spade terminals, crimp two 4.8mm female spade connectors on to appropriate lengths of wire and then attach the other ends to the remaining polarised header connector (it doesn't matter which way around they go). The spade connectors can then be fitted to the switch terminals and the connector plugged into the main board.

If the switch has solder tabs instead of spade terminals, just solder the leads directly to it.

Finishing it

Now for the final steps. First, ensure that the power switch is off, then install the battery cells. That done, plug the ribbon cable into the main board and fasten down the lid of the case.

Because the switch header connector on the main board only just clears the underside of the control board, you may need to fold the ribbon cable slightly to the left, so that it doesn't get sandwiched between them. If it does, the lid won't sit properly and screwing it down could bend the board.

Also, check that there is no uninsulated copper where the leads exit the polarised header connectors. If there is, it could short to the underside of the control PC board. If there is some exposed wire, you will need to insulate it with electrical tape or heatshrink tubing.

Finally, it's a good idea to use the neoprene seal provided with the case, even though it is no longer water-tight thanks to the various holes. However, the seal will help keep the lid on tight.

That's it – construction is complete. Switch the unit on and make sure it works as expected. If not, remove the lid, unplug the ribbon cable from the main board, and check that the cells have been installed correctly and that the power switch is wired correctly.

That's all we have space for this month. In Part 3, we will explain how to use the various modes and describe the various features in detail.

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Cheaper Than Chips

TechnoTalk

Mark Nelson

Up to now, the chief raw material of modern electronics has been silicon, which is neither in short supply nor desperately expensive. Nevertheless, imagine for a moment what difference a cheaper substitute for silicon might bring about – Mark speculates, so just read on.

SILICON, the eighth most widely occurring element on earth, is at the core of most electronic circuitry. Although widespread, it very seldom occurs as a pure free element, but this is not a major problem, since for most commercial purposes it is used without being separated.

Its widest use is in the construction industries, and the amount of very highly purified silicon that ends up in semiconductor electronics is less than ten per cent of the total usage. However, its widespread use in integrated circuits, essential to most computers and consumer electronics, also in optical fibres, means that a great deal of modern technology and connectivity depends on silicon to a critical degree.

Gut reaction

Now comes news that a far cheaper material has been found for making logic gates, and no, it's not an April Fools' joke.

Scientists at London's Imperial College have successfully demonstrated that they can build some of the basic components for digital devices out of human material, which could pave the way for a new generation of biological computing devices. The researchers have demonstrated that they can build logic gates, the fundamental building blocks on which our entire digital age is based, for processing information in devices such as computers and microprocessors, out of harmless gut bacteria and DNA.

'Without logic gates, we could not process digital information,' says Imperial's Prof. Richard Kitney. 'We hope that our work will lead to a new generation of biological processors, whose applications in information processing could be as important as their electronic equivalents.'

Bioprocessors

Although it's still a long way off, the team suggests that these biological logic gates could one day form the building blocks in microscopic biological computers. Devices may include sensors that swim inside arteries, detecting the build up of harmful plaque and rapidly delivering medications to the affected zone.

Other applications might include sensors that detect and destroy cancer cells inside the body, and pollution monitors that can be deployed in the environment, detecting and neutralising dangerous toxins such as arsenic.

The advantage of these biological logic gates over previous attempts is that they behave like their electronic counterparts, say the researchers. The new biological gates are also modular, which means that they can be cascaded to make different types of logic gates, paving the way for more complex biological processors to be built.

Circuit bugs

So how do these biological logic gates work? In one experimental set-up, biological logic gates replicate the way that electronic logic gates process information by either switching 'on' or 'off'. The scientists constructed a type of logic gate called an AND gate from bacteria called *Escherichia coli* (*E. Coli*), which is normally found in the lower intestine. The team altered the *E. Coli* with modified DNA, which reprogrammed it to perform the same switching on and off process as its electronic equivalent when stimulated by chemicals.

These gates are modular too. The researchers have shown that the biological logic gates can be connected together to form more complex components, in a similar way that electronic components are integrated into composite chips. In another experiment, the researchers created a NOT gate, and combined it with the AND gate to produce the more complex NAND gate.

The next stage of the research will see the team trying to develop more complex circuitry that comprises multiple logic gates. One of the challenges faced by the team is finding a way to link multiple biological logic gates together, similar to the way in which electronic logic gates are linked together to enable complex processing to be carried out.

In support of this, Prof. Martin Buck, who was also involved with this research, argues that the next stage of their research could lead to a totally new type of circuitry for processing information. 'In the future, we may see complex biological circuitry processing information using chemicals, much in the same way that our body uses them to process and store information,' he said.

Of course, making connections to biological components is not like soldering onto stripboard. In bioelectronic circuits, the measured output is the nature of the electrical conductivity that is observed in the bioelectronic computer, which comprises specifically designed biomolecules that conduct electric current in highly specific manners based upon the initial conditions that serve as the input of the bioelectronic system.

Grow your own gates

Could common bacteria, preferably grown outside the body, replace silicon, making digital components truly cheaper than chips? It's hard to tell, because the capabilities of these fledgling biocomputers are minute in comparison to commercially available non-bio computers. On the other hand, the potential exists in the most powerful, complex computational machine known to currently exist—the biocomputer that is the human brain.

Ahmad Khalil and James Collins, two scientists from Boston, Mass. (US), are optimistic, stating that synthetic biology is bringing together engineers and biologists to design and build novel biomolecular components, networks and pathways, and to use these constructs to rewire and reprogram organisms.

'These re-engineered organisms will change our lives over the coming years, leading to cheaper drugs, 'green' means to fuel our cars, and targeted therapies for attacking superbugs and diseases, such as cancer,' they proclaim. Their paper on synthetic biology discusses topics as varied as biosensing, biomaterials, biosynthetic pathways and riboswitches in a level that I, for one, cannot hope to comprehend, but you can read it all at: **www.ncbi.nlm.nih.gov/pmc/articles/PMC2896386** There is a clear pictorial chart of these processes at: **www.bu.edu/abl/files/nrg_poster.pdf**

Not all technology innovations come to fruition of course; a few years ago I reported here how scientists at Oxford University had managed to use fungal enzymes to create a hydrogen fuel cell that could run a digital watch. Sadly, the trail for these button cells went cold in 2008. Rest assured I shall be monitoring developments in this field.

CAPACITOR LEAKAGE ADAPTOR FOR DMMs

By JIM ROWE

Here's a cut-down version of the Digital Capacitor Leakage Meter we described in November 2011. Instead of using a PIC microcontroller and an LCD panel to display the leakage current, this version connects to your DMM to provide the readout. It provides the same range of seven different standard test voltages (from 10V to 100V) and can measure leakage currents down to 100 nanoamps!

WHY would you need to measure capacitor leakage current? In case you missed the November 2011 article, here's a summary of the introduction we provided there.

In theory, capacitors are not supposed to conduct direct current – apart from a small amount when a DC voltage is first applied to them and they have to 'charge up'.

With most practical capacitors, using materials like ceramic, glass, polyester or polystyrene – even waxed paper – as their insulating dielectric, the only time they do conduct any DC is during charging. That's assuming they haven't been damaged, either physically or electrically. In that case they may well conduct DC as a steady 'leakage current', showing that they are faulty.

But as many *EPE* readers will be aware, things are not this clear cut with electrolytic capacitors, whether they are aluminium or tantalum. All brand new electrolytic capacitors conduct a small but measurable DC current, even after they have been connected to a DC source for sufficient time to allow their dielectric oxide layer to 'form'. In other words, all electrolytic capacitors have a significant leakage current, even when they are 'good'.

The range of acceptable leakage current tends to be proportional to both the capacitance and the capacitor's rated voltage. Have a look at the figures given in the Leakage Current Guide opposite. The current levels listed there are the maximum allowable before the capacitor is regarded as faulty.

So, an instrument capable of measuring the leakage current of capacitors can be very handy in many areas of electronics.

Commercially available capacitor leakage current meters are expensive (ie, over £500) and even the Capacitor Leakage Meter we described in the November 2011 issue will probably cost you over £50 to build. That's why we've developed a cut-down version described in this article, which lets you make all of the same measurements with your existing digital multimeter (DMM).

The Adaptor is easy to build and will have a much lower cost than the November 2011 meter, while still providing the same choice of seven different standard test voltages: 10V, 16V, 25V, 35V, 50V, 63V or 100V. It is also able to make current measurements from 10mA down to a fraction of a microamp. So it's capable of making leakage current tests on the vast majority of capacitors in current use.

It's built into a compact UB1-size jiffy box, and is battery powered (6 x AA alkaline cells). This makes it suitable for the workbench or the service technician's tool kit.

How it works

The Capacitor Leakage Adaptor's operation is straightforward, as you can see from the block diagram of Fig.1. There are two functional circuit sections, one is a selectable DC voltage source (on the left) which generates one of seven different preset voltages when the TEST button is pressed and held down.

The second section is a simple current-to-voltage converter (on the right) which is used to generate a voltage proportional to the direct current passed by the capacitor under test, so that it can be measured easily using your DMM.

Any direct current passed by the capacitor being tested flows down to ground via resistor R2, which therefore acts as a current shunt. The voltage drop across R2 is then passed through an output buffer, which feeds your DMM. The DMM is set to its 0V to 2V DC voltage range, which allows its readings to be easily converted into equivalent current levels.

So that's the basic arrangement. The reason for resistor R1, in series with the output of the test voltage source, is to limit the maximum current that can be drawn from the source, in any circumstances. This prevents damage to either the voltage source or the current-to-voltage converter sections, in the event of the capacitor under test having an internal short circuit. It also protects R2 and the output buffer from overload when a capacitor (especially one of high value) is initially charging up to one of the higher test voltages.

CAPACITOR LEAKAGE CURRENT GUIDE

TYPE OF CAPACITOR	Maximum leakage current in microamps (µA) at rated working voltage						
	10V	16V	25V	35V	50V	63V	100V
Ceramic, Polystyrene, Metallised Film (MKT, Greencap etc.), Paper, Mica	LEAKAGE SHOULD BE ZERO FOR ALL OF THESE TYPES						
Solid Tantalum* < 4.7µF	1.0	1.5	2.5	3.0	3.5	5.0	7.5
6.8µF ⋮ 47µF	1.5 ⋮ 10	2.0 ⋮ 10	3.0 ⋮ 15	4.0 ⋮ 16	6.5 ⋮ 17	7.0 ⋮ 19	9.0 ⋮ 24
Standard Aluminium Electrolytic# <3.3µF	5.0	5.0	5.0	6.0	8.0	10	17
4.7µF ⋮ 10µF	5.0	5.0 ⋮ 8.0	6.0 ⋮ 13	8.0 ⋮ 18	12 ⋮ 25	15 ⋮ 35	23 ⋮ 50
15µF ⋮ 100µF	8.0 ⋮ 50	11 ⋮ 230	19 ⋮ 300	25 ⋮ 330	38 ⋮ 420	100 ⋮ 500	230 ⋮ 600
150µF ⋮ 680µF	230 ⋮ 500	280 ⋮ 600	370 ⋮ 780	430 ⋮ 950	520 ⋮ 1100	600 ⋮ 1300	730 ⋮ 1560
1000µF ⋮ 4700µF	600 ⋮ 1300	730 ⋮ 1590	950 ⋮ 2060	1130 ⋮ 2450	1340 ⋮ 2900	1500 ⋮ 3300	1900 ⋮ 4110

* Figures for Solid Tantalum capacitors are after a charging period of one minute.
# Figures for Aluminium Electrolytics are after a charging/reforming period of three minutes.

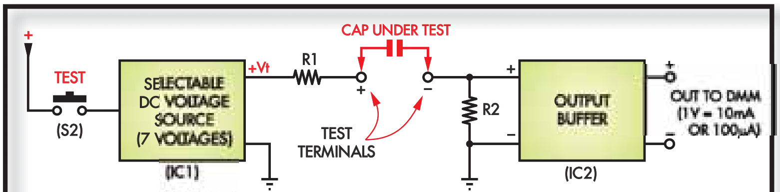


Fig.1: block diagram of the adaptor shows it has two elements: a selectable DC voltage source and a simple current-to-voltage converter.

Resistor R1 has a value of 10kΩ, which was chosen to limit the maximum charging and/or short-circuit current to 9.9mA, even on the highest test voltage range (100V).

At this stage, you may be wondering how the adaptor can allow your DMM to read leakage currents down to less than a microamp, when it also has to cope with charging currents of up to 9.9mA. The answer is that the current-to-voltage converter section of the adaptor actually has two current ranges, which are selected by switching the value of shunt resistor R2.

The default value of R2 is 100Ω, which provides a 0 to 10mA range for the capacitor's charging phase (ie, when TEST button S2 is first pressed). But when (and if) the measured current level falls below 100μA, pushbutton S4 can be pressed to switch the value of R2 to 10kΩ, providing a 0 to 100μA range for a more accurate low leakage current measurement.

Circuit description

Take a look at the full circuit diagram for the Capacitor Leakage Adaptor, see Fig.2. The selectable DC voltage source is based around IC1, an MC34063 DC/DC controller IC, used here in a 'boost' configuration in conjunction with autotransformer T1 and fast switching diode D2.

We vary the circuit's DC output voltage by varying the ratio of the voltage divider in the converter's feedback loop, connecting from the cathode (K) of D2 back to IC1's pin 5 (where the voltage is compared with an internal 1.25V reference).

The 270kΩ resistor forms the top arm of the feedback divider, while the 36kΩ and 2.4kΩ resistors from pin 5 to ground form the fixed component of the lower arm. These give the divider an initial division ratio of 308.4kΩ/38.4kΩ or 8.031:1, to produce a regulated output voltage of 10.04V. This is the converter's output voltage when selector switch S1 is in the '10V' position.

When S1 is switched to any of the other positions, additional resistors are connected in parallel with the lower arm of the feedback divider, to increase its division ratio and hence increase the converter's output voltage.

For example, when S1 is in the 25V position, this connects the 270Ω, 8.2kΩ, 5.1kΩ, 2.0kΩ, 200Ω, 2.4kΩ, 150Ω and 3.6kΩ resistors (all in series) in parallel with the divider's lower arm, changing the division ratio to 283.954kΩ/13.954kΩ or 20.35:1. This produces a regulated output voltage of 25.44V.

The same kind of change occurs in the other positions of switch S1, producing the various preset output voltages shown.

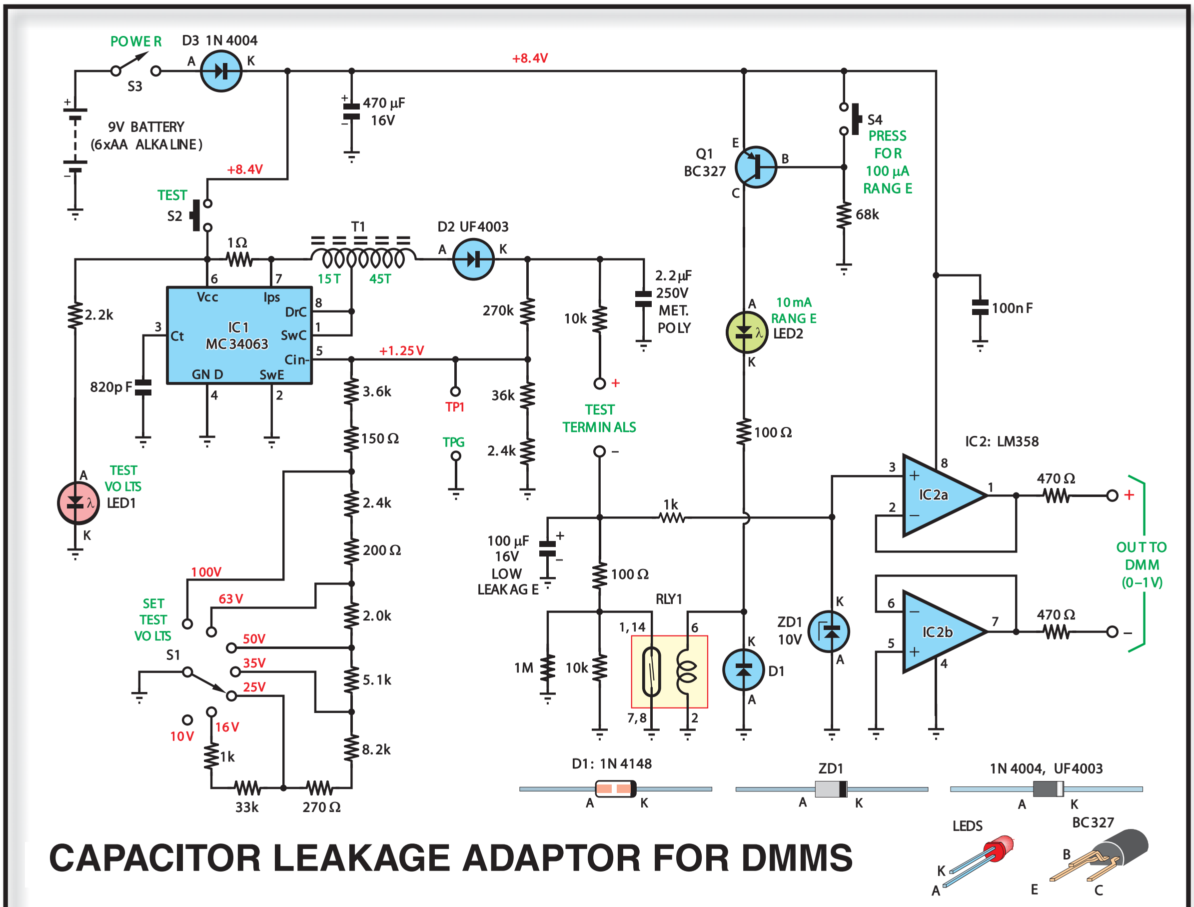


Fig.2: here's the complete circuit diagram for the Adaptor. At the beginning of each test it measures on its 10mA range, but if the current drops below 100μA it can switch to a 100μA range.

(Although the test voltages shown are nominal, with the specified 1% tolerance resistors used for the divider resistors, they should all be well within ±4% of the nominal values because the 1.25V reference inside the MC34063 is accurate to within 2%.)

Note that IC1 only generates the selected test voltage when test pushbutton switch S2 is pressed and held down. This is because IC1 only receives power from the battery when S2 is closed, allowing the converter circuit to operate and thus charge the 2.2µF/250V metallised polyester reservoir capacitor.

Specification

Test voltages .... 10V, 16V, 25V, 35V, 50V, 63V or 100V

Leakage current ..... from 10mA down to less than 100nA (0.1µA), via two ranges: 0 to 10mA (default) and 0 to 100µA (manually selected).

Both ranges convert these current values into an output voltage range of 0 to 1000mV DC, allowing all measurements to be made on the DMM's 0 to 1V or 0 to 2V range.

The adaptor's default 10mA range is current limited to provide protection from damage due to shorted capacitors, or the charging current pulse of high-value capacitors.

Power..................... Internal 9V battery (6 x AA alkaline cells).

Current drain .... Varies between 1mA and 125mA, depending on the test voltage and the current range in use.

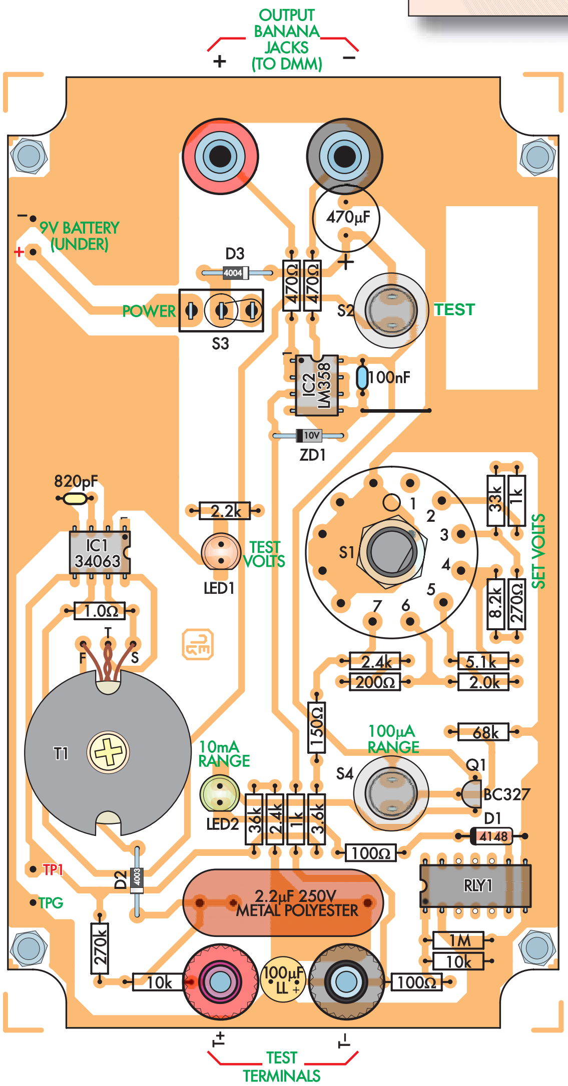
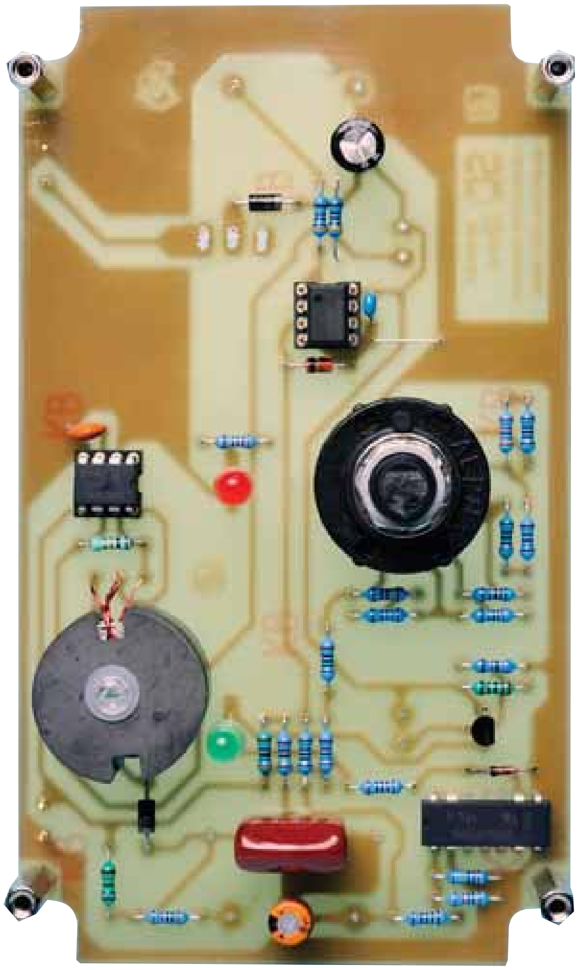


Fig.3: with the exception of the test terminals, DMM output jacks and three of the switches, all components mount on one PC board.



Here's a photograph which matches the diagram at left. In this case, the terminals and the two pushbutton switches are not shown on the board because they mount on the front panel and connect to the PC board via short lengths of tinned copper wire (one of the last steps in assembly).

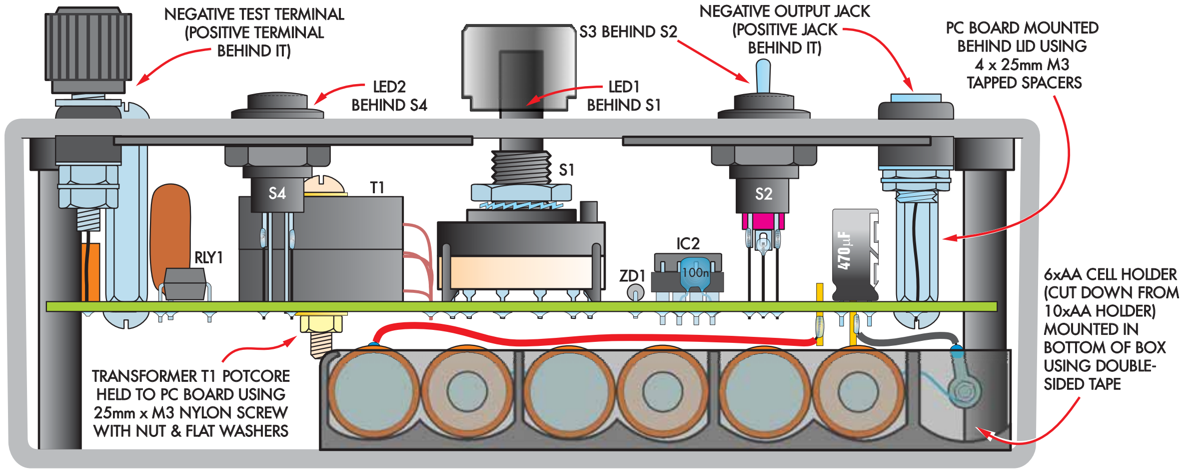


Fig.4: a side-on view 'through' the wall of the UB1-size box, showing how everything goes together. The 6xAA cell holder must be mounted at one end, as shown here, to avoid fouling the screw holding the transformer to the PC board.

The test voltage is then made available at the positive test terminal via the 10kΩ current limiting resistor, R1.

Current-to-Voltage converter

Now let us look at the current-to-voltage converter section, which is virtually all of the circuitry below and to the right of the negative test terminal.

The 100Ω, 1MΩ and 10kΩ resistors, connected between the negative test terminal and ground, correspond to the current shunt labelled R2 in Fig.1, with the contacts of reed relay RLY1 used to change the effective shunt resistance for the adaptor's two ranges. For the default 0 to 10mA 'charging phase' range, RLY1 is energised and connects a short circuit across the parallel 1MΩ/10kΩ combination, making the effective shunt resistance 100Ω. For the more sensitive 100μA range, RLY1 is turned off, opening its contacts and connecting the parallel 1MΩ/10kΩ resistors in series with the 100Ω resistor to produce an effective shunt resistance of 10kΩ.

Relay RLY1 is turned on or off by transistor Q1. When power is first switched on via switch S3, Q1 is switched on by forward bias current applied to its base (B) via the 68kΩ resistor to ground. It therefore conducts about 10mA of collector current, which energises RLY1 and also causes LED2 to light – indicating that the adaptor is operating in the 10mA current range. But if the capacitor's current reading (on the DMM) drops down to below 100μA, pressing pushbutton switch S4 and holding it down causes Q1 to switch off. As a result, LED2 and RLY1 both turn off as well, switching the adaptor to its 0 to 100μA range.

The 100μF low leakage capacitor, in parallel with the shunt, routes any AC signal from the capacitor being tested around the shunt. This prevents ripple from the switch-mode supply from corrupting the reading.

Regardless of which current range is in use, the voltage drop developed across the shunt resistance (as a result of any current passed by the capacitor under test) is passed to the non-inverting input of IC2a, one half of an LM358 dual op amp. IC2a is configured as a voltage follower with a voltage gain of unity, feeding the positive output terminal of the adaptor via a 470Ω isolating resistor.

So what is the purpose of IC2b? It is connected as a voltage follower in much the same way as IC2a, except that its non-inverting (+) input is connected directly to ground, and its output is used to drive the negative output terminal. Its purpose is to balance out most of the input offset of IC2a, so that the adaptor's effective output voltage, when there is no current flowing through the test terminals, is much less than 1mV.

All of the adaptor's circuitry operates directly from the 9V battery, via polarity protection diode D3 and, of course, S3. The total current drain when in 'standby' (ie, with TEST button S2 not pressed) is about 11mA in the default 10mA current range, or 1mA if S4 is pressed to switch it into the 100μA range. The current level increases to between 25mA and 125mA when S2 is pressed and held down to generate the test voltage and perform the actual leakage current test.

Construction

Virtually all of the components used in the Capacitor Leakage Adaptor are mounted on a single PC board measuring 145mm × 84mm. This board is available from the *EPE PCB Service*, code 842. The board is mounted under the lid (which becomes the adaptor's front panel) of a UB1-size plastic box (157mm × 95mm × 53mm) via four 25mm-long M3 tapped spacers. Six AA alkaline cells provide power, mounted in a cut-down 10-cell holder secured to the bottom of the box.

Both the voltage selector switch (S1) and the DC/DC converter's step-up transformer (T1), wound on a 26mm ferrite pot core, mount on the board, the latter using a 25mm-long M3 nylon screw and nut.

The only components not mounted directly on the PC board are power switch S3, pushbutton switches S2 and S4, the two test terminals and the two output banana jacks. These are all mounted on the box front panel, with their rear connection lugs extended down via short lengths of tinned copper wire to make their connections to the board. All of these assembly details should be fairly clear from the diagrams and photos.

Board assembly

The printed circuit board component layout is shown in Fig.3, together with a board photograph. To begin fitting

the components on the PC board, it is suggested you fit the wire link, located just to the right of IC2 and above the position for rotary switch S1. Next, fit the four 1mm terminal pins to the board – two for the test point at lower left and two at upper left for the battery clip lead connections. Follow these with the sockets for IC1 and IC2, which are both 8-pin devices.

Now fit the fixed resistors. These are 1% tolerance metal film components, apart from the 1.0Ω resistor just above the connecting leads of T1 and below IC1. This 1Ω resistor should be a 0.5W carbon composition type. Check each resistor's value with a digital multimeter (DMM) as you insert and solder them, to ensure they all go in the right places.

Next, you can fit the two lower-value capacitors and the large 2.2μF metallised polyester capacitor, followed by the two polarised electrolytic capacitors – see Fig.3 for their orientation. Now fit the mini DIL relay, making sure its locating groove is as shown in Fig.3.

Voltage selector switch

You can now fit voltage selector rotary switch S1, which mounts with its indexing spigot at 12 o'clock (Fig.3). Just before you fit it, you should cut its spindle to a length of about 13mm and file off any burrs, so it's ready to accept the knob during final assembly.

After it has been fitted to the board, remove its main nut/lock washer combination, and turn the spindle by hand to make sure it's at the fully anticlockwise limit. Then refit the lock washer, making sure that its stop pin goes down into the hole between the moulded '7' and '8' digits. Check that the switch is now 'programmed' for the correct seven positions, simply by clicking through them by hand.

With S1 fitted, you can add the four diodes. Don't mix them up: D1 is a low power 1N4148 'signal' diode, D2 is a UF4003 'fast' rectifier, D3 is a 1N4004 1A power diode and ZD1 is a 10V/1W Zener. Use the component layout diagram (Fig.3) as a guide to their orientation when you're fitting each one to the board.

Next, fit transistor Q1, followed by the two 5mm LEDs. The red one is used as LED1 and the green one as LED2. They are both mounted vertically with their leads left at almost full length, so that the lower surface of their bodies is about 23mm above the surface of the board. Note that the shorter lead, next to the flat on the body, is the cathode (K). This allows them to just protrude through the matching holes in the lid/front panel when the assembled board is attached behind it.

At this stage, your board assembly is very close to complete, with the main task remaining being to wind transformer T1 and fit it to the board. You'll find the full details on how to do this in the separate 'Winding' panel.

Once the transformer has been fitted to the board, you can attach the four 25mm M3 tapped spacers to it as well. These each attach very close to each corner of the board, using 6mm long M3 screws passing up from the underside – see Fig.4 and photographs.

Now all that remains to complete the board assembly is to plug IC1 and IC2 into their sockets. Place it aside while you prepare the case to receive it.

Preparing the case

There are no holes to be drilled in the lower part of the case (the battery holder can be held securely in place using strips of 'industrial' double-sided adhesive foam tape), but the lid does need to have holes drilled for the various switches, LEDs and input/output connectors.

The location and dimensions of all these holes are shown in the diagram of Fig.5, which is actual size, so it (or a photocopy) can also be used as a drilling template. The larger holes are easily made by drilling them all first with a 7mm twist drill and then carefully enlarging them to size using a tapered reamer.

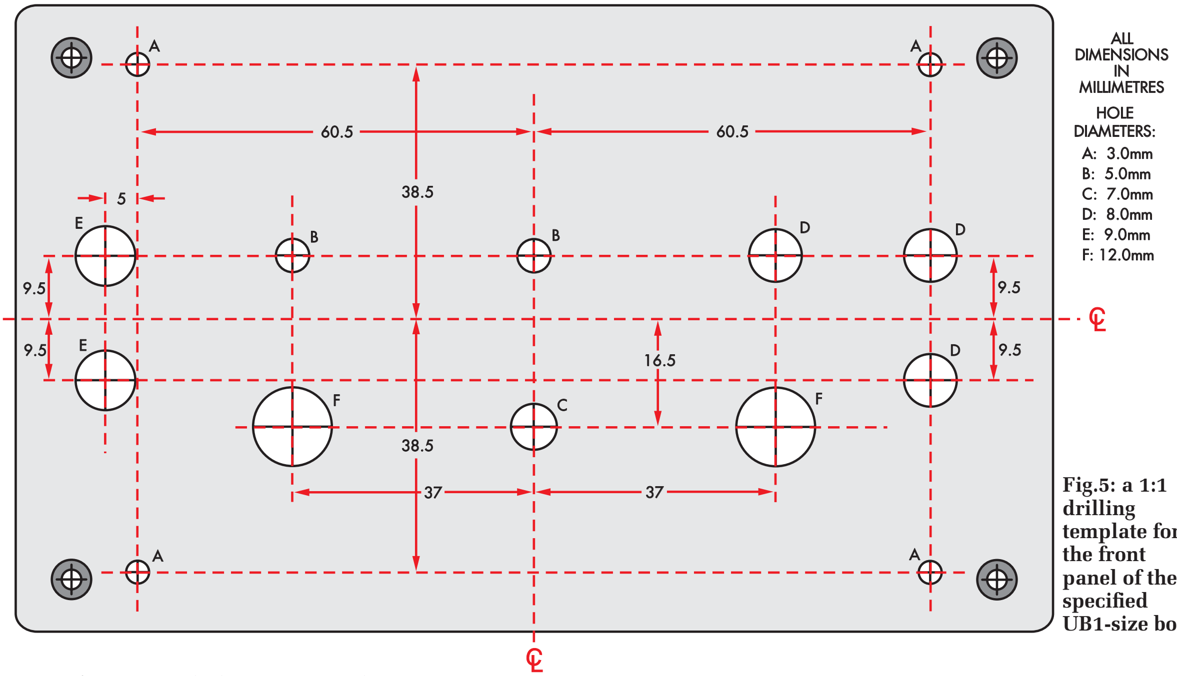


Fig.5: a 1:1 drilling template for the front panel of the specified UB1-size box.

Parts List – Capacitor Leakage DMM Adaptor

1 PC board, code 842, available from the *EPE PCB Service*, size 145mm × 84mm
1 UB1-size plastic box, 158mm × 95mm × 53mm
1 Single-pole rotary switch, PC mounting (S1)
2 SPST mini pushbutton switch (S2, S4)
1 SPDT mini toggle switch, panel mounting (S3)
1 Mini DIL reed relay, SPST with 5V coil (RLY1)
2 Premium binding posts, 1 × red and 1 × black
2 4mm banana jack sockets, 1 × red and 1 × black
1 16mm diameter fluted instrument knob
1 Ferrite pot core pair, 26mm OD
1 Bobbin to suit pot core
1 3m length of 0.5mm diameter enamelled copper wire
1 25mm M3 nylon screw and nut and two flat washers
2 8-pin DIL IC sockets
4 1mm dia. PC board terminal pins
4 25mm long M3 tapped spacers
8 6mm long M3 machine screws, pan head
1 10× AA battery holder (flat, side by side) – see text

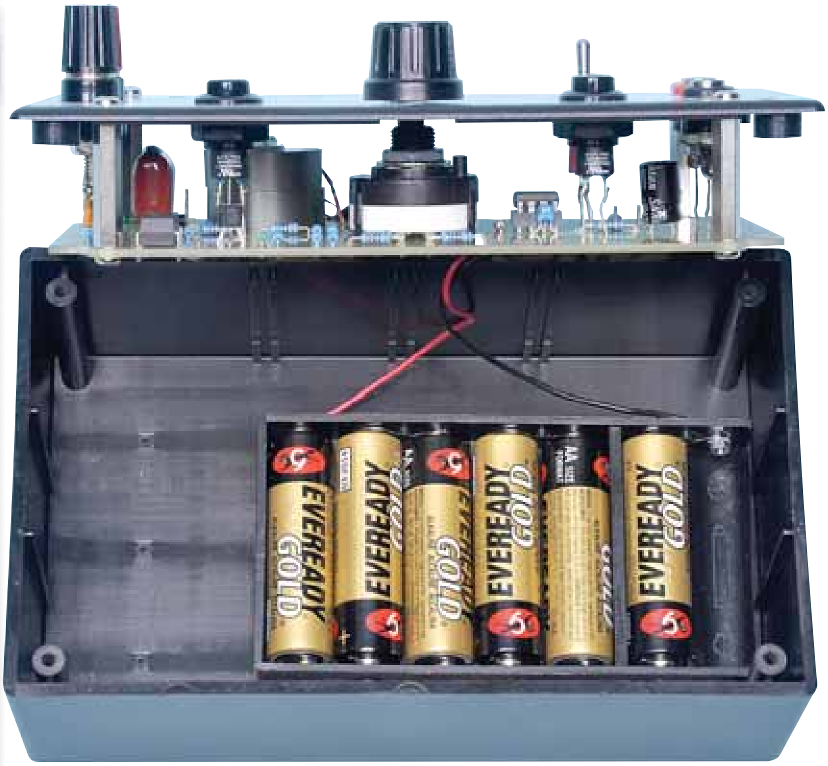
Semiconductors
1 MC34063 DC/DC converter controller (IC1)
1 LM358 dual op amp (IC2)
1 BC327 *PNP* switching transistor (Q1)
1 10V 1W Zener diode (ZD1)
1 5mm red LED (LED1)
1 5mm green LED (LED2)
1 1N4148 100mA diode (D1)
1 UF4003 fast 1A diode (D2)
1 1N4004 1A diode (D3)

Capacitors
1 470µF 16V PC elect
1 100µF 16V low leakage elect
1 2.2µF 250V (or 100V) metallised polyester
1 100nF multilayer monolithic ceramic
1 820pF disc ceramic

Resistors (0.25W 1% unless specified)

1 1MΩ	1 270kΩ	1 68kΩ
1 36kΩ	1 33kΩ	2 100Ω
2 10kΩ	1 8.2kΩ	1 5.1kΩ
1 3.6kΩ	2 2.4kΩ	1 2.2kΩ
1 2.0kΩ	2 1kΩ	2 470Ω
1 270Ω	1 200Ω	1 150Ω

1 1.0Ω 0.5Ω carbon (5%)



'Opened out' view showing the PC board 'hanging' from the front panel.

We have prepared an artwork for the front panel if you would like to make it look neat and professional. This can be photocopied (Fig.6), the resulting copy can either be covered with self-adhesive clear film or, better still, laminated, for protection against (finger) grease before it is glued to the lid/front panel.

Mount switches S2, S3 and S4 on the panel, followed by the binding posts, used as the meter's test terminals, and the banana sockets, used for the output connections to your DMM.

Tighten the binding post and banana socket mounting nuts firmly, to make sure that they cannot come loose with use. Then use the second nut of each post and socket to attach a 4mm solder tag, plus a 4mm lockwasher to make sure they don't work loose either.

You can now turn the lid assembly over and solder 'extension wires' to the connection tags of the three switches, and also the solder tags fitted to the rear of the binding posts and sockets. These wires should all be about 30mm long and cut from tinned copper wire (about 0.7mm diameter).

The next step is to prepare the battery holder. Because you can't buy a six-way flat AA holder (at least we couldn't find one) we cut down a ten-way AA holder.

The last three cell positions are removed altogether (at the 'negative lead' end) and then the eyelets are drilled out and used to attach the contact spring for the sixth cell position and also the contact spring and negative lead connection lug at the end of the removed section.

This will allow you to re-attach the negative lead's connection lug to the contact spring for the sixth cell using a 6mm-long M2 machine screw and nut. The seventh cell position is still retained to support the sixth cell connection spring and the negative lead connection lug.

The converted battery holder can now be fitted inside the main section of the box at lower right, with the connection lead side uppermost. Mount it using double-sided adhesive foam as mentioned earlier, or simply a strip of 'gaffer' tape.

Final assembly

You should now be ready for the only slightly fiddly part of the assembly operation: attaching the PC board assembly to the rear of the lid/front panel.

This is only fiddly because you have to line up all of the extension wires from switches S2, S3 and S4, the two test terminals and the output banana sockets with their matching holes in the PC board, as you bring the lid and board together. At the same time you have to line up the spindle of switch S1 and the two LEDs with their matching holes in the front panel.

This is actually easier to do than it sounds, so just take your time and the lid will soon be resting on the tops of the board mounting spacers. Then you can secure the two together using four 6mm-long machine screws.

Now it's simply a matter of turning the complete assembly over and soldering each of the switch and terminal extension wires to their board copper pads. Once they are all soldered, you can clip off the excess wires with sidecutters.

If you find this description a bit confusing, refer to the assembly diagram in Fig.4. This will hopefully make everything clear.

Next, solder the bared end of the red (positive) battery holder lead to the positive (+) battery terminal pin on the PC board, and the black (negative) battery holder lead to the negative pin alongside.

You can now fit six AA alkaline cells into the battery holder (make sure you fit them with the correct polarity) and your new Capacitor Leakage Adaptor should be ready for its initial checkout.

Initial checkout

You'll need to use a twin test lead to connect the adaptor's output to the input jacks of your DMM. The DMM should also be set to measure DC voltage, and to its 0V to 1V or 0V to 2V range if it's not auto-ranging.

Switch on the adaptor's power using S3 and the green Range LED2 should light – showing that the adaptor is operating, in standby mode and in the default 10mA current range. If you now press pushbutton switch S4, the range change button, LED2 should go dark. This shows that the range switching circuitry is operating. But your DMM should still be giving a 'zero' reading. At this point you can stop pressing S4.

Next, try pressing test button S2. This should cause red Test Volts LED1 to glow, indicating that power is now being applied to the test voltage generation circuitry. If there is no capacitor or other component connected across the test terminals, your DMM should still be giving a reading of zero.

DMM readings

Assuming all has gone well at this point, your adaptor is probably working correctly.

However, if you want to make sure, try shorting the two test terminals. Then set S1 to the '100V' position, and press Test button S2. The DMM reading should change to a value corresponding to 9.9mA (ie, 990mV), representing the current drawn from the nominal 100V source by the 10kΩ current-limiting resistor and the 100Ω current shunt resistor inside the adaptor.

Don't worry if the current reading is a bit above or below the 9.9mA figure. As long as it's between about 9.2mA (920mV) and 10.6mA (1.06V), things are OK.

With the terminals still shorted together, you can try repeating the same test for each of the other six test voltage positions of switch S1.

You should get a reading on the DMM corresponding to approximately:

6.25mA (625mV) on the 63V range
4.95mA (495mV) on the 50V range
3.46mA (346mV) on the 35V range
2.48mA (248mV) on the 25V range
1.58mA (158mV) on the 16V range
990μA (99mV) on the 10V range.

If the readings you get are close to these, your Capacitor Leakage Adaptor is working correctly.

If this is the case, switch off the power again via S3 and then complete the final assembly by lowering the lid/PC board assembly into the case and securing the two together using the four small self-tapping screws supplied. Make sure you also remove the shorting wire between the test terminals.

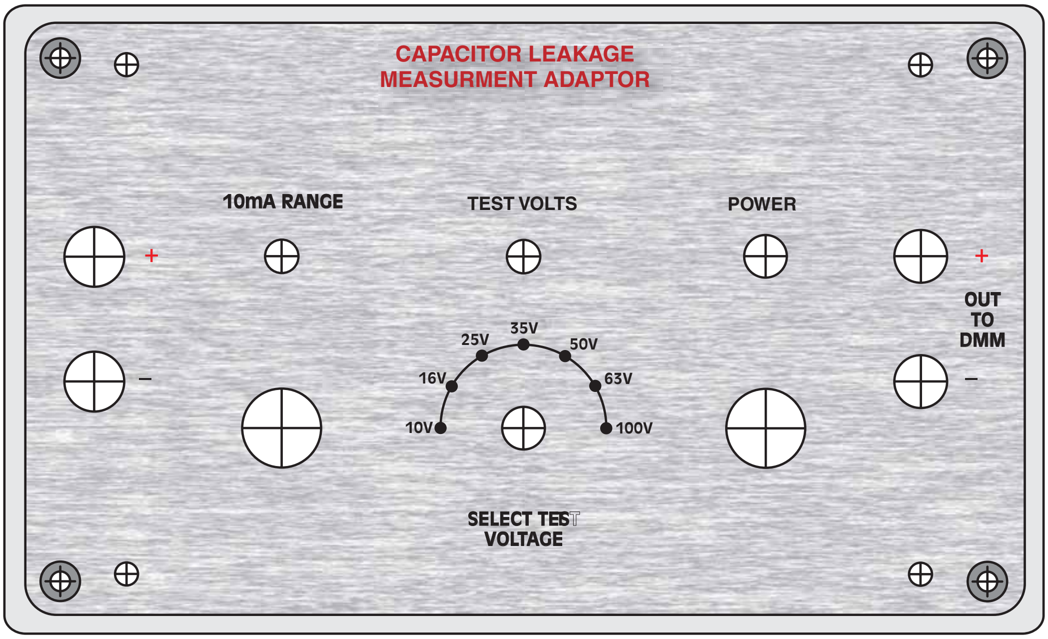


Fig.6: same-size front panel artwork.

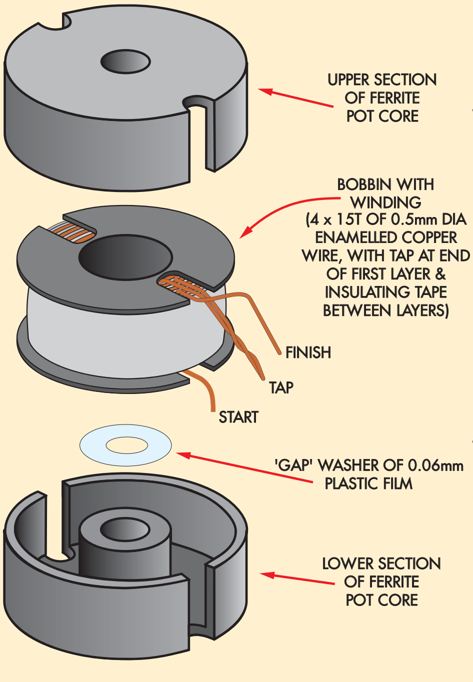
Winding autotransformer T1

The step-up autotransformer T1 has 60 turns of wire in all, wound in four 15-turn layers. As you can see from the assembly diagram at right, all four layers are wound on a small nylon bobbin using easily handled 0.5mm-diameter enamelled copper wire. Use this diagram to help you wind the transformer correctly.

Here's the procedure: first wind on 15 turns, which you'll find will neatly take up the width of the bobbin providing you wind them closely and evenly. Then to hold them down, cover this first layer with a 9mm-wide strip of plastic insulating tape or 'gaffer' tape.

Next, take the wire at the end of this first layer outside of the bobbin (via one of the 'slots') and bend it around by 180° at a point about 50mm from the end of the last turn. This doubled-up lead will be the transformer's 'tap' connection.

The remaining wire can then be used to wind the three further 15-turn layers, making sure that you wind them in the same direction as you wound the first layer.



(ASSEMBLY HELD TOGETHER & SECURED TO PC BOARD USING 25mm x M3 NYLON SCREW & NUT)

Each of these three further layers should be covered with another 9mm-wide strip of plastic insulating tape just as you did with the first layer, so that when all four layers have been wound and covered everything will be nicely held in place.

The 'finish' end of the wire can then be brought out of the bobbin via one of the slots (on the same side as the start and tap leads) and your wound transformer bobbin should be ready to fit inside the two halves of the ferrite pot core.

Just before you fit the bobbin inside the bottom half of the pot core, there's a small plastic washer to prepare. This is to provide a thin magnetic 'gap' in the pot core when it's assembled, to prevent the pot core from saturating when it's operating.

The washer is very easy to cut from a piece of the thin clear plastic that's used for packaging electronic components, like resistors and capacitors.

This plastic is very close to 0.06mm thick, which is just what we need here. So the idea is to punch a 3mm to 4mm diameter hole in a piece of this plastic using a leather punch or similar, and then use a small pair of scissors to cut around the hole in a circle, with a diameter of 10mm. Your 'gap' washer will then be ready to place inside the lower half of the pot core, over the centre hole.

Once the gap washer is in position, you can lower the wound bobbin into the pot core around it, and then fit the top half of the pot core. The transformer is now ready for mounting on the main PC board.

First, place a nylon flat washer on the 25mm-long M3 nylon screw that will be used to hold it down on the board. Then pass the screw down through the centre hole in the pot core halves, holding them (and the bobbin with gap washer inside) together with your fingers.

Then lower the complete assembly down on the board, with the 'leads' positioned as shown in Fig.3, using the bottom end of the centre nylon screw to locate it in the correct position. When you are aware that the end of the screw has passed through the hole in the PC board, keep holding it all together, but up-end everything so you can apply the second M3 nylon flat washer and M3 nut to the end of the screw, tightening the nut so that the pot core is not only held together but also secured to the PC board.

Once this has been done, all that remains as far as the transformer is concerned is to cut the start, tap and finish leads to a suitable length; scrape the enamel off their ends so they can be tinned; and then pass the ends down through their matching holes in the board so that they can be soldered to the appropriate pads.

Don't forget to scrape, tin and solder BOTH wires which form the 'tap' lead – if they are not connected together, the transformer won't produce any output.

Using it

The Capacitor Leakage Adaptor is very easy to use, because all you have to do is connect the capacitor you want to test across the test terminals (with the correct polarity in the case of solid tantalums and electrolytics), after connecting the adaptor's output sockets to the input jacks of your DMM.

Then turn on the DMM and set it to measure DC volts.

Now set the adaptor's selector switch S1 for the correct test voltage and turn on the power (S3), whereupon LED2 should light. To begin the actual test, press and hold down Test button S2.

What you may see first on the DMM is a reading of the capacitor's charging current, which can be as much as 9.9mA (with high value caps), but it will then drop back as charging continues. How quickly it drops back will depend on the capacitor's value.

With capacitors below about 4.7μF, the charging may be so fast that the first reading will often be less than 100μA (10mV).

If the capacitor you're testing is of the type having a 'no leakage' dielectric (such as metallised polyester, glass, ceramic or polystyrene), the current should quickly drop down to less than 10μA (1mV).

And if you press button S4 to switch down to the 100μA range, you should be able to see the DMM reading fall down to zero. That's if the capacitor is not faulty, of course.

On the other hand, if the capacitor is one with a tantalum or aluminium oxide dielectric with inevitable

leakage, the current reading will drop more slowly as you keep holding down the Test button.

In fact, it will probably take up to a minute to stabilise at a reasonably steady value in the case of a solid tantalum capacitor, and as long as three minutes in the case of an aluminium electrolytic.

(That's because these capacitors generally take a few minutes to 'reform' and reach their rated capacitance level.)

As you can see from the guide table earlier, the leakage currents for tantalum and aluminium electrolytics also never drop down to zero, but instead to a level of somewhere between about 4.1mA and 1μA, depending on both their capacitance value and their rated working voltage.

So, with these capacitors, you should hold down the test button to see if the leakage current reading drops down to the 'acceptable', level as shown in the guide table, and preferably even lower.

If this happens, then the capacitor can be judged 'OK', but if the current never drops to anywhere near this level it should definitely be replaced.

Low leakage

What about low leakage (LL) electrolytics? Well, the current levels shown in the guide table are basically those for standard electrolytics rather than for those rated as 'low leakage'.

So, when you're testing one which is rated as 'low leakage', you'll need to make sure that its leakage current drops well below the maximum values shown in the guide table. Ideally, it should drop down to no more than about 25% of these current values.

A final tip: when you're testing non-polarised (NP) or 'bipolar' electrolytics, these should be tested twice – once connected to the terminals one way around, and then again connected with the opposite polarity.

That's because these capacitors are essentially two polarised types, internally connected in series, back-to-back. If one of the dielectric layers is leaky but the other is OK, this will only show up in one of the two tests. *EPE*

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WIB FAQs

By MAURO GRASSI

The Web Server In a Box (WIB) project has been very popular and lots of them have been built. Here we collect a number of 'frequently asked questions' (FAQs) that may help anyone experiencing difficulties in building and setting up the WIB. We also provide the answers to some common technical questions and feature requests.

Software releases

AT THE time of writing, the released firmware for the WIB includes versions between 5.30 and 5.40. Most questions in this article relate to versions 5.30, 5.31 and 5.32.

Version 5.40 is the latest and fixes two problems with earlier versions (see later). It has been made available to the kit suppliers and is also available for free download from the *EPE* website (**www.epemag.com**). Future batches of kits should contain the new firmware version (5.40) or later.

This FAQ compilation refers to the original hardware of the WIB, which used the dsPIC33FJ64GP802 microcontroller. However, it is now possible to use the dsPIC33FJ128GP802 chip as well. This device is pin-for-pin compatible, but has double the program memory.

By using this new chip, it would now be possible to incorporate many new features, including an ethernet-based bootloader. This and other features will be considered for a future upgrade to the WIB.

Common set-up questions and problems

Q *I have changed a setting in the* **settings.txt** *file using a text editor, but the setting does not seem to have changed in the WIB. Why is that?*

A This can be confusing at first, and is one of the most common traps that constructors can fall into.

Basically, the settings are stored in binary form in the **values.dat** file. The **settings.txt** file is only for the default values (if there is no **values.dat** file), as happens on the very first boot up.

The WIB creates the **values.dat** file from the **settings.txt** file if it does not exist. If it does exist, it uses the settings stored in the **values.dat** file.

This scheme made the firmware simpler because changes to settings can be stored easily in binary form but are more difficult to store in a human-readable file like the **settings.txt** file. However, the human-readable file is useful for setting up the default values.

In order to change the settings to those in the **settings.txt** file, you need to first delete the **values.dat** file and then reboot the WIB. A new **values.dat** will then be created, with the settings taken from the **settings.txt** file.

This is done by clicking the 'Restore Defaults' button in the supplied default website (ie, you don't have to switch the WIB off and then on again in order to reboot it).

Q *There is a* **csettings.txt** *file in the supplied default website, as well as the default* **settings.txt** *file. What is the* **csettings.txt** *file for?*

A The **csettings.txt** file is generated by the WIB and should not be modified, as it has no effect on the settings of the WIB. The **csettings.txt** file is created by the WIB at runtime to store the current settings in a human-readable form. This is used in the 'Create Defaults' function, where the **csettings.txt** file is copied to the **settings.txt** file.

Q *Should I retain the directory information when I unzip the contents of* **ewswebsite.zip** *to obtain the supplied website (available from the January 2012 downloads section of the* EPE *website)?*

A No, the files should all be unzipped into the root folder of the memory card, disregarding any original path information stored in the zip archive.

Q *There is a file named* **0711109A.hex** *in the supplied default website, what is this file for?*

A This file contains the firmware image for the latest version of the WIB. It can be left on the memory card and will not affect the operation of the WIB, or it can be deleted. It is a small file, so it will not take up much space on the memory card. Note that if it is left on the memory card, it can then be accessed like other pages served by the WIB.

Q *I am having trouble logging into the WIB with the username and password as set in the* **settings.txt** *file. Alternatively, some setting in the* **settings.txt** *file does not seem to be being parsed properly. Why is that?*

A There could be a number of reasons for not being able to log on to the WIB using the username and password, as stored in the **settings.txt** file. First, as explained earlier, the **settings.txt** file contains the default values, not the actual values of the WIB. The actual settings are stored in binary form in a file called **values.dat**.

If you wish to revert to the settings in the **settings.txt** file, you should delete the **values.dat** file and reboot the WIB as explained earlier.

Additionally, when the WIB reads the values from the **settings.txt** file, it will only parse a line if it finds a newline at its end. So a setting may not be being parsed simply because there is no newline at the end of the line (this happened to a reader). Remember, every entry in the **settings.txt** file should be on a separate newline-terminated line.

So, if you can't log on with the username and password in the **settings.txt** file, it may be because the last line in the **settings.txt** file does not contain a newline. In the default **settings.txt** file supplied, the password setting is last. While the file supplied has a newline, if you change this line, the last line may no longer have a newline and so the password will not be set.

Q *The WIB seems to be working correctly, but it cannot send emails. There is an entry in the* **log.txt** *file with a hexadecimal error code. What does this mean?*

A The hexadecimal error codes shown in the **log.txt** file relating to sending emails are standard SMTP (simple mail transfer protocol) error codes. These are returned by the SMTP server that the WIB is connecting to. The list of SMTP error codes can be found online.

The 'Email From' may also need to be set if you are using your ISP's SMTP server and are sending the email to a foreign email address, especially to a Gmail or Hotmail address. If not set correctly, an additional error may occur because of some SMTP server anti-relaying rules to do with spam reduction.

The relevant error is 0x0227 (Error 551). We found this during testing with a particular (Australian) SMTP server, for example. Changing the 'Email From' field may solve this problem. Remember the 'Email From' field is simply what is shown as the sender when you receive an email from the WIB, so it is not a crucial setting.

Note that SMTP settings for 'Email Server User' and 'Email Server Password' are only used if the SMTP server you are sending to requires authorisation. Most ISP SMTP servers don't require this (so you can send anonymous emails when you have an Internet account) but some do require authorisation.

If the Email User and Password settings are set, the WIB starts an SMTP session by trying to authenticate with the server. If the SMTP server doesn't require this, then it may terminate the SMTP connection before the email is sent, returning an 0x01F7 error (Error 503), even if the username/password combination is correct.

To avoid this problem, remove the two settings from the **settings.txt** file, delete the **values.dat** file and reboot the WIB.

Q *Can the microcontroller in the WIB be programmed using the simple* dsPIC/PIC Programmer *described in the May 2010 issue of* EPE*? If not, how can it be easily programmed?*

A No, the *dsPIC/PIC Programmer* cannot program the dsPIC33-FJ64GP802 chip. The latter microcontroller was not available at the time the programmer was designed and so is not supported. Instead, it is best to use a programmer like the PICkit3 from Microchip, together with their free MPLAB software.

Q *When I try to log on to the WIB using its IP address from the address bar of my web browser, it loops continually without loading the home page. Why is that?*

A When you type the IP address into a browser, without qualifying any extra path information, it assumes, as default, that you are requesting the **index.htm** file. The **index.htm** file provided with the default website for the WIB uses the refresh metatag to redirect to the home page, which is the **home.cgi** page.

On some web browsers, or rather on some versions of those browsers, this has the effect of looping continually without loading the page. Specifying the complete path (eg, 192.168.0.34/home.cgi) rather than only the IP address should solve this problem. Alternatively, changing the contents of the **index.htm** page can solve the problem.

Q *Can you give an example of what values are needed for connecting a straight 0V to 5V sensor to the analogue inputs of the WIB, rather than a 3.3V sensor, as described in the original article?*

A You will need to connect your sensor to a voltage divider to bring its output within a 0V to 3.3V range. This can be done by connecting a divider that divides by 5/3.3 = 1.52 (eg, 10kΩ and 20kΩ).

You will then need to calculate the correct values for your sensor and enter them in the gradient and Y-intercept fields in the **variables.cgi** page of the default website.

The instructions to calculate these values are in the original articles.

Q *The LM317 voltage regulator used to derive the 3.3V rail for the WIB runs hot to the touch. Is this normal, and how can the heat be reduced?*

A It is normal for the regulator to get hot and so the original design specifies a heatsink. The higher the input voltage delivered by the plugpack the more heat that will be dissipated. To reduce the heat dissipation, you should use a 6V plugpack.

Q *Can the WIB take digital inputs? Can the WIB send an email notification when a digital input changes? For example, can the WIB send an email notification when a reedswitch closes or opens?*

A While nominally the WIB only accepts four analogue inputs, they can also be used to accept digital inputs. If the digital input swings between 0V and 3.3V, it is easy to set the minimum and maximum values at about the middle of this range. However, the minimum should be below the maximum to allow for hysteresis.

The WIB can then send emails when the state of the digital input changes. If using a reedswitch, you do the same but use a pull-up resistor to the 3.3V rail, or a pull-down resistor to 0V.

If the digital input is not within a 0V to 3.3V range, you will have to implement some kind of level translation. This can sometimes be easily achieved by using an open collector output and a pull-up resistor to the 3.3V rail.

Q *Can the digital outputs of the WIB be pulsed for a predetermined amount of time?*

A Not with the current versions of the firmware, although this could easily be incorporated if sufficient program memory were available. You could have an extra variable (or four extra variables for independent control) to hold the pulse time in milliseconds, and new commands to pulse the outputs.

These are easy additions to the firmware, but there is not enough program memory to make the modification with the original hardware. It is certainly possible with the 128KB version chip, and may be incorporated in a new design in the future. If readers really want this function, they could delete parts of the code to make room for it.

Q *Can the WIB be used with Windows-based FTP programs? In particular, can it be used with programs such as FileZilla?*

A With versions of the firmware before 5.40, some FTP programs like FileZilla did not like the WIB's response to the PWD command. This was fixed in firmware version 5.40 in response to a reader's report. In any case, versions without this fix should still work with the recommended FTP command line Windows client, as explained in the original article.

Note that the WIB is not guaranteed to work with other FTP clients because it does not support the full FTP command set.

USB support and file system storage

Q *Are there any plans to make the WIB work with an NTFS file system?*

A No, there are no plans to make the WIB support file systems other than FAT. As NTFS is primarily a Windows file system, you would lose the portability that FAT offers.

Note that you can read FAT with either a Windows or Linux PC and with a Mac. Also, there is little appreciable gain in performance in going from FAT to NTFS for the WIB project (there is for a PC though).

FAT is perfectly adequate for the WIB (it is limited to 2TB, but there is not going to be an MMC/SD/SDHC memory card that can store 2TB any time soon!) It is true that there is also a single-file size limit with FAT that would be much less restrictive with a more up to date file system like NTFS. However, the limit is around 4GB and we think this is more than adequate for the application.

If you are going to serve a page of that size it will take a considerable amount of time using the WIB – it is a huge amount of data.

There are also licencing issues with NTFS that are avoided with a FAT file system as used in the WIB (there are issues with FAT too). The FAT code used in the WIB is open source and the NTFS code would also certainly have a larger memory footprint.

NTFS is suitable for modern operating systems running on PCs with abundant resources, but it is much less suitable for embedded systems with few resources like the WIB. For all these reasons, FAT is a good choice as a file system for the WIB and for many other embedded systems.

Q *Can a USB Flash drive be used to store website files for the WIB, instead of using an MMC/SD/SDHC memory card? If not, are there any plans to modify the WIB to do this?*

A To interface to a USB Flash drive would require implementing a USB host interface, including a supply to power the USB. The WIB does not have the hardware to do this. For this reason, it would not be viable to modify the WIB to support a USB Flash drive.

We believe a memory card is adequate for the application and has the advantage of being quite compact. USB Flash drives are perhaps more easily transported and removed, but in this application, we assume that the memory card will be seldom removed.

Q *Are there any plans to make the WIB work with an external hard drive, either via a USB port or natively?*

A No, there are no plans to change the WIB's mass storage from its current medium. We believe that the current capacities that can be purchased in SDHC cards (up to 32GB) are more than sufficient for the applications that the WIB will be used for.

While hard drives offer cheaper and larger storage capacities, the complexity of the interface rules it out for the WIB. The microcontroller has no native USB host support, and there is no other hardware on the WIB to support connection to a USB device. Adding a native hard drive interface would be even more complex.

Added to this, a memory card uses less power and is more compact, reliable and faster than a hard drive.

Q *Can the WIB be used with 3G wireless modems with a USB port (dongles)?*

A No, since the WIB does not implement a USB host, it cannot be used with such 3G modems. The WIB can only be used with an Ethernet connection.

To be able to use a USB modem, you would need a USB host and the WIB has no such hardware support as it stands. However, there are 3G wireless modems which have an Ethernet connection, and you should be able to use such a modem with the WIB.

Miscellaneous questions

Q *Is it possible to put a slot in the external case so that the memory card can be removed or inserted, without having to take the case apart to get at the card?*

A When the design was conceived, we assumed that the memory card would only infrequently be inserted or removed, as files can be uploaded or downloaded using an FTP client.

It would be possible to house the WIB in a different case with a slot that would allow easier access to the memory card. In fact, you could even use it in a freestanding manner without a case, or leave out one of the side panels if you use it with the originally specified case.

Q *The RJ45 connector from Amphenol used in the WIB (CON2) has pins 4 and 5 and pins 7 and 8 each internally shorted, and then connected via 75Ω resistors to a single 1nF capacitor connected to 0V. Would this cause problems if it were connected to a PoE (Power over Ethernet) system? Wouldn't some of the 75Ω resistors be destroyed?*

A The termination used in the WIB is the one recommended in the datasheet for the ENC28J60 Ethernet controller (obtained from the Microchip website). The 75Ω resistors and the 1nF capacitor are for EMI reduction and ESD protection, and the 1nF (2kV) capacitor connects to the metal shield of CON2 for this purpose.

The RJ45 connector used in the WIB is not designed for PoE applications, and it would be a problem if the PoE host simply applied power. But that doesn't happen – PoE hosts test the resistance between the terminals before doing so.

In other words, a device configured for PoE must have the correct resistance before it is supplied with power. Since the WIB doesn't present the correct resistance, the PoE host will not (or should not) apply power to it (an RJ45 connector for PoE would add capacitors in series with the 75Ω resistors).

Serial port questions

Q *Can data be logged from the serial port of the WIB?*

A You cannot log data from the serial port using the current versions of the WIB firmware. However, you can log data from the four analogue inputs to the SD card and email them to a nominated account.

Q *Is it possible to communicate in both directions with the onboard serial port of the WIB?*

A No, it is not possible with current versions of the firmware to receive serial data with the WIB.

It would not be difficult to modify the source code to allow the WIB to receive data into a buffer, or to write it to a file on the memory card, perhaps with network time information as well. You could also build in a serial server that would listen to serial commands and run functions, depending on the received data.

For example, you could have the WIB send an email every time a certain sequence of serial data is received, or send the serial data received in an email.

When the firmware was written, program memory was at a premium and some features had to be dropped. The serial port functions for sending data and now taking up memory could perhaps be replaced with code for receiving data.

Website functionality questions

Q *Can the WIB firmware be easily modified to include support for PHP and ASP server-side scripting?*

A No, it is not possible – the WIB supports only client-side scripting. Server-side scripting is intended for more powerful PC-based or embedded servers, but is not really suitable for the WIB.

We cannot rule out some kind of server-side scripting for a future upgrade, but it may not be on the scale of a full-featured language like PHP, simply because the hardware is not powerful enough.

Q *Is it possible to use a typical LAMP (Linux, Apache, MySQL, PHP) installation with the WIB?*

A No, it is not possible. Such installations are for full-featured PC-based or embedded servers that are much more powerful than the WIB. The WIB is not a full-featured server, nor does it have the speed or memory (or even hardware architecture) to run such an installation.

Q *Can the WIB support a website for online shopping using a shopping cart?*

A No, the WIB does not support a shopping cart application. There are a number of reasons. First, it does not support server-side scripting and second, it would *not* be ideal from a *security* point of view, as the WIB does not support encryption either.

Feature requests

Q *Does the WIB respond to ping requests? Does the WIB implement a DHCP client?*

A No, the WIB does not support ICMP and will not reply to ping requests. Early versions of the firmware supported ping, but that was dropped to make room for other features due to limited memory.

DHCP client support was also dropped for the same reason.

Q *How can the firmware be updated if there are future changes?*

A Currently, the only way to do this is to use a Microchip PICkit3 programmer. This is because the WIB doesn't have a bootloader, which would allow its program memory to be rewritten with an upgraded version of the firmware via an Ethernet connection. The microcontroller supports RTSP (Run Time Self-Programming), but there was simply not enough program memory to implement such a feature.

However, as stated at the beginning of this article, it is possible to use the dsPIC33FJ128GP802 chip instead of the original microcontroller. This latter device is pin-for-pin compatible, but has double the program memory. By using this chip, it would be possible to incorporate many new features, including an Ethernet-based bootloader, and we may make this feature available in a later version of the project.

Q *What are some of the feature requests that have been submitted by readers? Will they be implemented in the future?*

A Several readers have modified the firmware so that it does not delete the variable log files on reboot and to immediately log the variables on reboot, without waiting for the first log interval to elapse. Some readers have also added extra digital outputs and inputs via extra hardware, although the four analogue inputs can also be used as digital inputs.

There are no plans at the moment to incorporate these features in the standard firmware for the WIB.

Q *What are some of the feature requests that you have received from readers and which of those are viable? What other add-ons are possible?*

A We have had many requests from readers for features. Among these are:

(1) Better security, using encryption at least for the HTTP headers

(2) Support for server-side scripting like PHP

(3) Connection of additional sensors, including perhaps digital interfaces for sensors (eg, 1-wire Dallas)

(4) Battery backed-up power supply, including a mechanism to monitor mains voltage

(5) Using the WIB for controlling a number of mains-powered appliances (eg, to power cycle computers through the web server)

(6) A bootloader to allow for easy firmware updates

(7) Faster Ethernet connection and Wi-Fi (wireless) connection.

The ones that we think are viable are: (1), (3), (5), (6), and we could also add DHCP client support and ICMP support. Server-side scripting of some form could be incorporated, but certainly not in the form of PHP, so we think that (2) is not viable.

We think (4) is too specialised and thus not viable. Note that many computers can be woken up using their LAN interface remotely (wake-on-LAN), so (5) would really only be for controlling mains devices other than PCs with a wake-on-LAN feature.

Note that the Microchip TCP/IP stack is also fully integrated with Wi-Fi support, and Microchip also supplies the hardware for Wi-Fi. As such, Wi-Fi is also possible, but would depart from the original design substantially.

Again, although Microchip now provide a 100Mbps Ethernet controller, it comes in an SMD package which would thus also depart from the original design substantially, so (7) is probably not viable (it would be a new hardware project).

When you exclude firmware features, there are also many other hardware add-on boards that could be designed. The WIB Time Display Module published in the March 2012 issue of *EPE* is one such item, and one reader has used an LCD rather than a LED display, with good results.

Known bugs and errata

Q *Are there any known bugs and workarounds for the WIB?*

A Yes, there are two known problems with firmware versions that are fixed in version 5.40.

The first problem occurs when using an IP address for the WIB other than 192.168.0.x, eg, a 10.1.1.x address. Most people will be using a 192.168.0.x address, so this issue will not be apparent.

If you assign an IP address other than 192.168.0.x, the WIB does not correctly ask for login information for file extensions set to private, exposing a *security risk*. For example, the **settings.txt** file can be viewed without logging in (the settings cannot be changed, however). Version 5.40 fixes this problem.

This problem can also be fixed by changing the default file permission to private (the default is public). This workaround works except that *all* files will then be private. If you want some to be public and some private, you will have to update the firmware.

The other problem is more minor, and is also fixed in version 5.40. It simply adds quotes around the PWD command reply of the WIB's FTP server. This is necessary to prevent some FTP programs from reporting errors with the WIB's response. Note that the command-prompt FTP client supplied with Windows can still be used with the WIB to transfer files to and from a PC.

ISP terms of use

PLEASE be aware that serving web pages may contravene your Internet plan's terms of use. You should check your ISP's terms to ensure that the WIB can be used with your account.

In some cases, it may be necessary to get a business account or a static IP address.

Kits and pieces, and EPE Chat Zone

IN THE January 2011 issue of *EPE*, we explained that the relevant SD Card Socket for WIB is no longer available as a separate component. (The manufacturer only supplies orders in quantities of 10,000 or more, which is not feasible for the hobby kit market.) We have tried to source a compatible alternative socket with the same pinouts, but so far without success.

While the *EPE* editorial team does research the projects that are published, unfortunately component 'disappearances' do occur occasionally. Late-breaking news and updates are available in the Shop Talk section of our forum, at: **www.chatzones.co.uk**.

Readers who wish to build WIB have essentially two main options: buy a complete kit, or purchase individual components.

For the latter, the March issue, included a brief explanation of how to 'hook-up' an alternative SD-Media socket to the board. This information is also available on our website (**www.epemag.com**).

A pre-programmed PIC is not available, so constructors will need to download the software and program the PIC using the Microchip PICkit3, together with their free MPLAB software.

For kit builders, two Australian suppliers advertise a complete set of parts: Jaycar and Altronics. *Before purchase*, we recommend you check that they include the correct SD-Media socket.

For Jaycar, you need kit number KC5489 from **www.jaycar.com.au**.

For Altronics, you need kit number K6210 from **www.altronics.com.au**

Last, but definitely not least, if you are having any problems with your WIB construction project; want to discuss an idea or explain an add on that you have designed/built; or simply want to chat about WIB in general, then do go to the *EPE Chat Zone* for lots of free and helpful WIB advice: **www.chatzones.co.uk**

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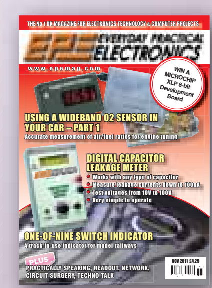

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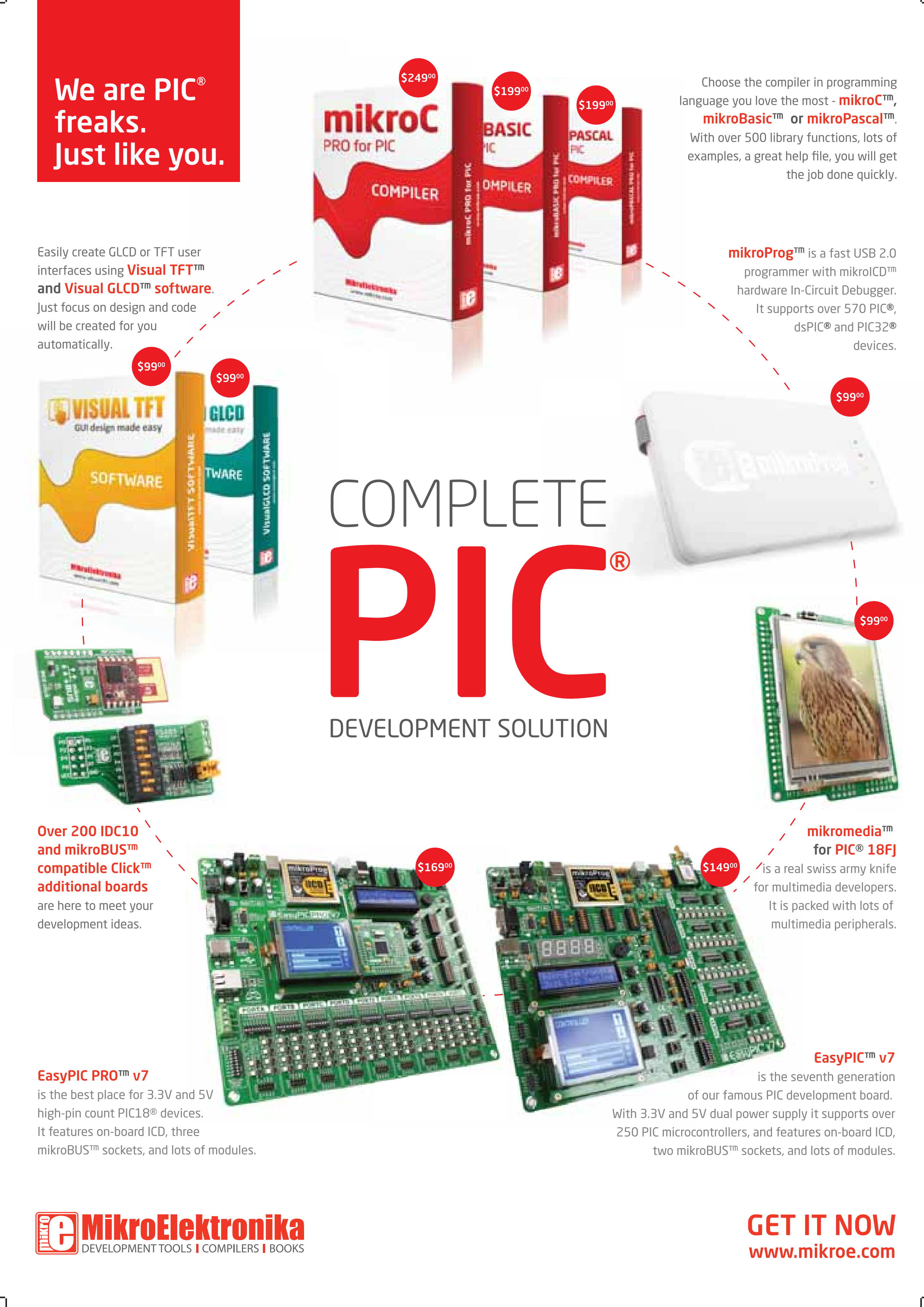

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INTERFACE

By Robert Penfold

Simple Electronic Thermometer

THE last *Interface* article (Feb '12) featured an 8-bit analogue-to-digital converter that interfaced to a PC via a virtual serial port. Although this interface offers only modest resolution and sampling rates, it is, nevertheless, suitable for a wide range of measurement applications.

One of these applications is temperature measurement, and a simple electronic thermometer is the subject of this month's column.

Scaling

With any measuring application that uses analogue-to-digital conversion, it is important to arrange things so that the system uses sensible scaling. The converter circuit covered in the previous article accommodates voltages in the range of 0V to 5V, and it is an 8-bit linear type. The maximum reading is therefore 255, and the circuit operates with increments of 19.607843mV!

In a temperature-measuring application, the sensor circuit should, therefore, be designed so that its output voltage varies at 19.607843mV per degree Celsius, per 0.5°C, or something equally convenient. The mathematics that convert the raw readings into corresponding temperature values will otherwise produce long rows of meaningless figures after the decimal point, or will introduce rounding errors.

An alternative approach is to alter the sensitivity of the converter to match up nicely with the output voltage range of the temperature sensor. An attenuator can be added ahead of the converter in order to increase the full scale voltage, or an amplifier can be used to increase the sensitivity of the circuit.

The ADC0804LCN is the converter chip used in the circuit featured in the previous *Interface* article, and it provides an alternative method of providing increased sensitivity. This basically just involves reducing the converter's reference voltage, which gives a corresponding reduction in the full scale voltage of the circuit.

A modified version of the converter, that enables the full-scale voltage to be varied from its normal 5V level to less than 1V, is shown in Fig.1. This circuit will not be described in detail here as it is essentially the same as the one featured in the Feb '12 article. The only difference is that an additional stage drives pin 9 of the converter chip (IC1), whereas this pin was previously left unconnected. Pin 9 connects to an internal potential divider circuit that provides the converter with a voltage that is equal to half the reference voltage used. In this case, the reference level is 5V and the potential at pin 9 of IC1 is therefore 2.5V.

The full-scale voltage of the converter can be reduced by using an external circuit to pull the voltage at pin 9 lower. The full-scale potential of the converter will still be twice the voltage at pin 9. Taking it to 1.5V, for example, would give a full-scale potential of 3V. Here the voltage is pulled lower using the variable voltage provided by R6 and VR1, which is applied to pin 9 of IC1 via a buffer amplifier that uses IC3 in a standard voltage follower circuit.

The LM358N used for IC3 is actually a dual device, but in this circuit one section is left unused, and there are no connections to pin 5 to pin 7 of this dual op amp. Note that the operational amplifier used for IC3 must be a type that can operate with a single supply rail. Most other types need dual rails.

Resistor R5 is needed to help the output stage (pin1) of IC3 pull pin 9 of IC1 to suitably low voltages. The preset potentiometer used for VR1 needs to be a high quality multiturn component.

Sense of proportion

There are several types of sensor devices that can be used to convert temperature into a corresponding voltage that can be read by the interface, but for most purposes the semiconductor variety are the most suitable. Semiconductor temperature sensors rely on the fact that the forward threshold voltage of a silicon diode varies with temperature.

The amount of change is not very great, and is typically only about 2mV per degree Celsius. On the plus side though, good linearity is maintained over a very wide temperature range.

The basic arrangement used for a semiconductor temperature sensor is shown in Fig.2. Diode D1 is the sensing element, and it is forward biased via a

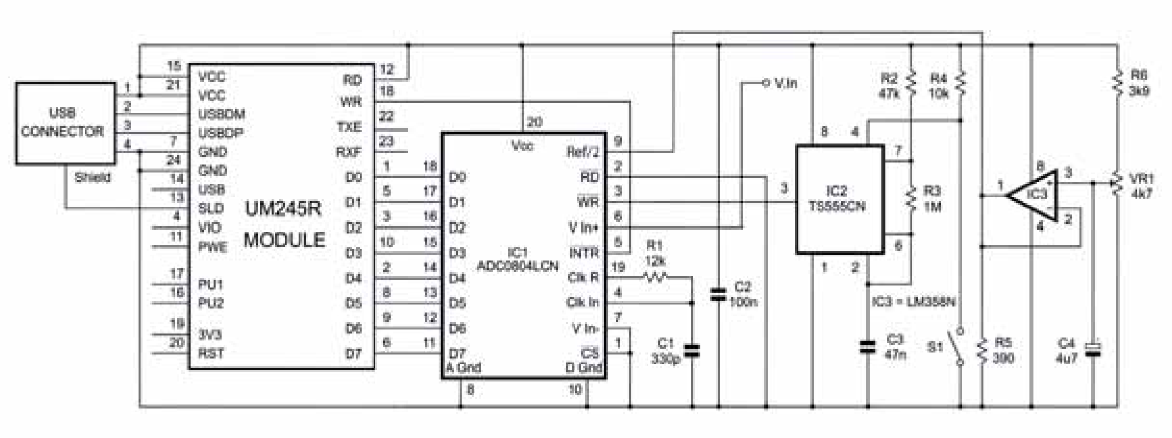

Fig.1. Adjusting preset VR1 enables the half reference level at pin 9 of IC1 to be reduced to less than one volt. The operational amplifier (op amp) used in the voltage follower (IC3) must be a type that is suitable for single supply operation

constant current source. The latter ensures that the operating conditions for the diode remain the same over the full temperature range covered.

The voltage developed across the sensing diode is typically about 0.65V at room temperature, and varies inversely to changes in temperature. In other words, the higher the temperature, the lower the output voltage.

In order to provide an output potential that is proportional to the sensed temperature, it is necessary to invert the signal and then provide further processing to remove the offset voltage and provide the required scaling. This can be achieved reasonably easily using discrete circuits, but these days it is far easier to use the various integrated circuit temperature sensors that provide all or most of the signal conditioning for you.

The LM35 is available in various versions with a variety of encapsulations. Fig.3 shows the leadout arrangement used for the TO92 cased version, which is the most readily available type. Note that this is a base view (ie, as viewed looking onto the leads of the device).

Fig.4 shows the circuit for an LM35 temperature sensor, and the only discrete component is capacitor C5. This helps to reduce problems with noise, and is especially important if, as will usually be the case, the LM35 is fitted in a probe and connected to the main circuit via a cable.

Scaling

The output voltage of the LM35 is 10mV (0.01V) per degree Celsius. Adjusting preset VR1 in the converter circuit for a full scale potential of 2.55V gives a resolution of 10mV, and readings from the converter are then directly in degrees Celsius. Perhaps more usefully, setting the full scale potential at 1.275V gives a resolution of 5mV, and dividing values from the converter by two then gives readings in degrees Celsius with increments of 0.5 degrees.

The slight downside of the increased resolution is that the maximum temperature reading is reduced from 150°C to 127.5°C. For most purposes, the increased resolution and slightly reduced maximum temperature is the better option.

It should be borne in mind that increasing the resolution of the converter also increases the likelihood of problems with noise giving jittery readings. This is true whether the converter itself is given a lower full-scale voltage or external amplification is used. Either way, greater care needs to be taken over the component layout in order to minimise the amount of noise that finds its way into the system.

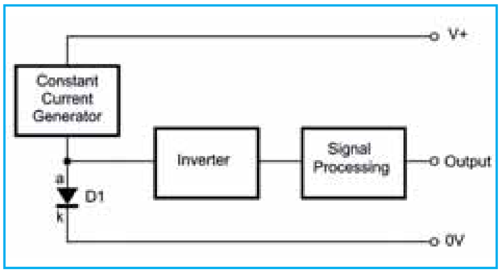

Fig.2. A semiconductor temperature sensor is based on a forward-biased diode. The output voltage reduces at only about 2mV to 3mV per degree Celsius, and a fair amount of signal processing is needed in a practical temperature measuring application

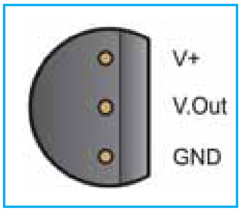

Fig.3. The base view for an LM35 temperature sensor that has a TO92 plastic encapsulation. The LM35 provides an output voltage that is equal to 10mV per degree Celsius

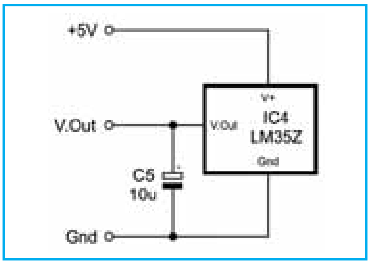

Fig.4. The circuit for an LM35 temperature sensor. The only discrete component required is capacitor C5, which is used to filter any noise picked up in the connecting cable

There are actually temperature sensing integrated circuits that have the necessary analogue-to-digital conversion built-in, and provide a digital output signal. These mostly provide a very high degree of accuracy from their 'state-of-the-art' circuitry, and represent a very good way of implementing a temperature interface.

Unfortunately, they are not really applicable in the current context, since they seem to require a two-way digital interface so that they can be set up to perform in the required manner. Here we will only consider simple temperature sensing devices that provide an analogue output signal.

There are numerous analogue temperature sensor chips to choose from, and as one would probably expect, the more expensive chips tend to offer a higher degree of linearity and accuracy than the lower cost types. The LM35 offers a good compromise between cost and performance, and it is very easy to use. You can pick up a pack of ten for less than £10 on eBay, and accuracy is typically ±0.5°C over the full operating range.

It will work well from a 5V supply and with a supply current of less than 60µA there are no significant problems with self-heating. It operates over a temperature range of –55°C to +150°V, although this becomes 0°C to +150°C when it is used with a single supply rail.

Software

The Visual BASIC routine in Listing 1 is all that is needed in order to provide an onscreen digital readout for the temperature interface. This is essentially the same as the listing

Listing 1

```
Imports System
Imports System.IO.Ports

Public Class Form1
    Dim WithEvents port As SerialPort = New _
     System.IO.Ports.SerialPort("COM8", 9600, Parity.None, 8, StopBits.One)

    Private Sub Form1_Load(ByVal sender As Object, ByVal e As _
                System.EventArgs) Handles Me.Load
        CheckForIllegalCrossThreadCalls = False
        If port.IsOpen = False Then port.Open()
    End Sub

    Private Sub port_DataReceived(ByVal sender As Object, ByVal e As _
      System.IO.Ports.SerialDataReceivedEventArgs) Handles port.DataReceived
        TextBox1.Text = (port.ReadByte / 2)
        If port.ReadExisting.Length = 0 Then
        End If
    End Sub
End Class
```

provided in the previous *Interface* article, but readings are divided by two before being displayed on the screen.

It is assumed here that the interface will be adjusted for a temperature range of 0°C to 127.5°C, with a resolution of 0.5°. The original listing will suffice if the interface is set for a range of 0°C to 150°C, with a resolution of one degree.

I added a 'Degrees Celsius' label to the form, as can be seen in Fig.5, which shows the system in operation. Remember that the COM port number used in the listing must be the one used for the virtual serial interface on your PC. It was COM8 for my PC, but in most cases it will be something different. With the serial port's driver software installed, the number for the port can be determined by going to the Ports section of the Windows Device Manager program.

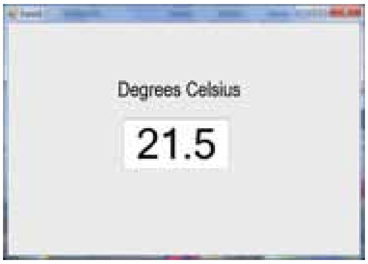

Fig.5. The program provided in Listing 1 gives a readout in degrees Celsius with a resolution of 0.5 degrees

Calibration

The circuit can be calibrated by setting the appropriate voltage at pin 9 of IC1, but for optimum accuracy it should be calibrated against an accurate thermometer. This is just a matter of subjecting the LM35 sensor and the reference thermometer to the same temperature and then adjusting preset VR1 so that the onscreen reading matches that of the reference thermometer.

Make sure that the thermometer and the sensor have had time to settle to the same temperature before adjusting VR1. Ideally, the calibration temperature should be fairly high at around half the full scale value or more.

A 'rough and ready' way of calibrating the unit is to place the sensor in boiling water, wait for readings to settle, and then adjust VR1 for a reading of 100 degrees. Of course, this requires the sensor to be housed in a probe assembly that is waterproof and can handle temperatures of 100°C or so. Bear in mind that some plastics melt at less than 100°C. Obviously, due care **MUST** be taken when the calibration process involves the use of hot liquids.

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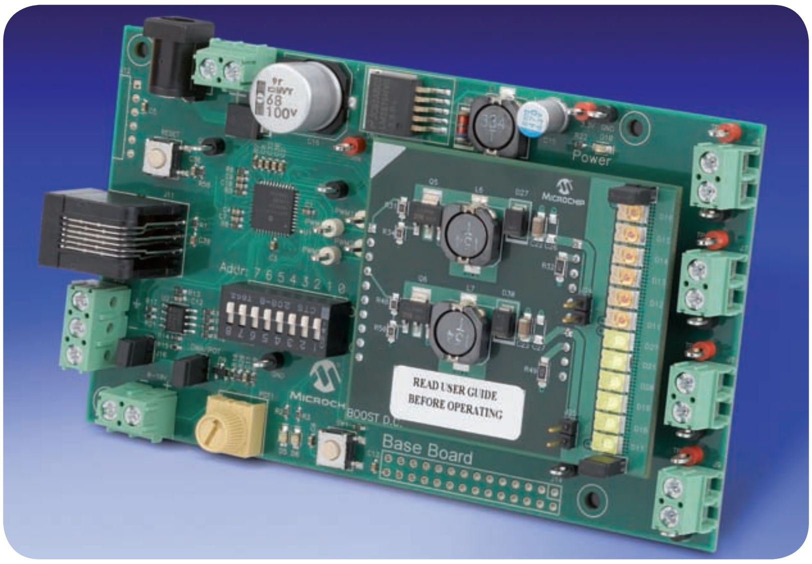

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BY IAN BELL

What's the comparison?

WE'VE received an email from ***Bond Piki*** who asks about part of the circuitry in the *230V 10A Full-Wave Motor Speed Controller* constructional project by John Clarke, from the June 2011 issue of *EPE*.

I just need to ask what's the formula for finding 5V peak-to-peak on the first op amp (oscillator/triangle generator), and what's the formula for finding the least voltage output and/or highest voltage output on the PWM comparator.

The full original schematic was on page 14 of the June 2011 issue. The section of the circuit relevant to the question is shown in Fig.1. In this month's article, we answer Bond Piki's questions, look at comparator circuits in general, and provide some further insights into the oscillator and comparator circuits used in the motor controller, which will be useful to readers who want to use these circuits in other applications.

In comparison

Both the PWM (pulse-width modulation) comparator and triangle waveform generator circuits use comparators. A comparator is a circuit which compares one analogue signal with another and outputs a binary logic signal based on the result of the comparison, or provides on/off switching of a load.

A comparator is similar to an op amp used without feedback (open loop); it has very high gain, thus for all but a very small range of input voltage differences the output will be at the lowest or highest output voltage available, typically close to the supply rails. These two saturated output voltages may represent Boolean 0 and 1. An op amp connected in this way behaves as a comparator, but usually specific circuits/chips, which are optimised for comparator operation, are employed. In the *230V 10A Full-Wave Motor Speed Controller*, the LM319 dual comparator chip is used.

The output circuit of the LM319 is shown in Fig.2. The output transistor Q16 is in open (or uncommitted) collector configuration. This is useful because loads such as relays or lamps can be connected between the output and supply. The LM319 can switch loads taking up to 25mA in this manner. Furthermore, multiple open collector outputs can be connected together without any short circuit problems. Then, if one or more of the linked output transistors is on, the load is switched on.

If we need the LM319's open collector output circuit to switch between two voltage levels, rather than just switch a load, then we need to provide a pull-up resistor. This is the purpose of the two 4.7kΩ resistors in the circuit in Fig.1. When Q16 in the LM319 (Fig.2) is on, the comparator's output is pulled down to ground by the transistor's low on resistance. When transistor Q16 is off the 4.7kΩ resistor in the external circuit pulls the output up to the supply voltage.

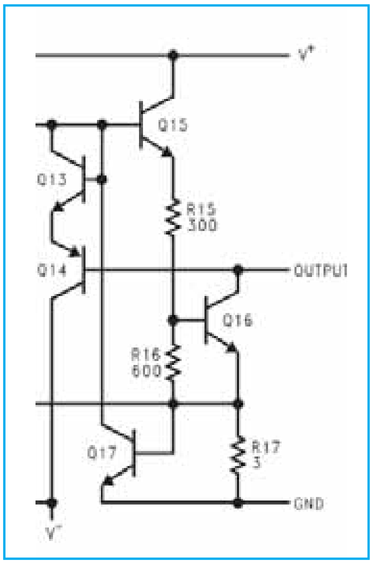

Fig.2. LM319 output circuit (from National Semiconductor datasheet)

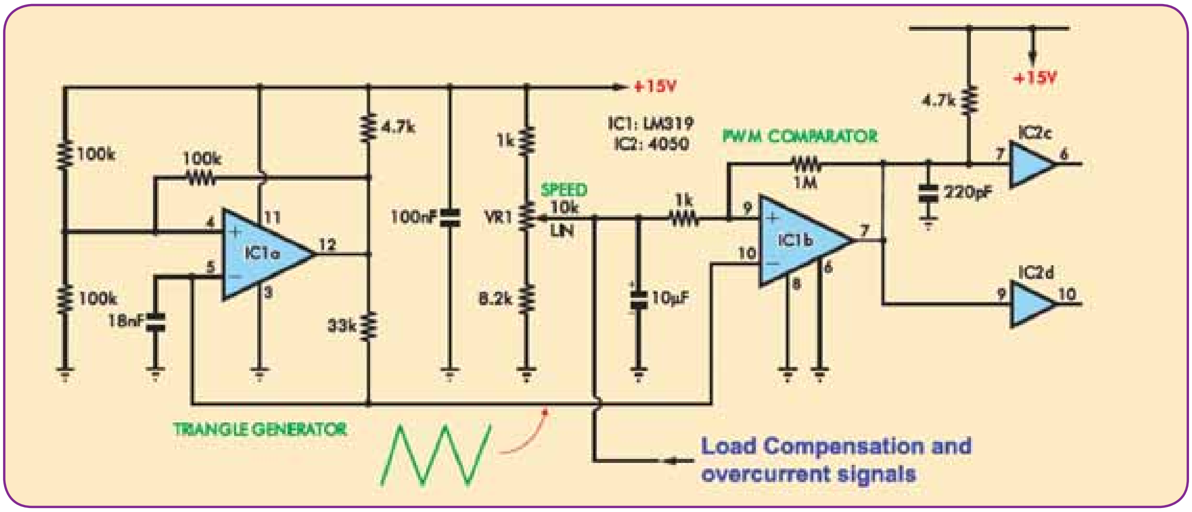

Fig.1. The triangle waveform generator and PWM comparator from the 230V 10A Full-Wave Motor Speed Controller

This answers Bond's question about the PWM comparator output voltage to some extent. Ideally, the comparator's output will switch between 0V and the supply voltage (15V). However, in practice, the minimum output voltage will depend on the collector-emitter saturation voltage of Q16 ($V_{CEsat,Q16}$) (in Fig.2) and any voltage dropped by R17.

The current in the LM319 output will be about 3.2mA (15V supply divided by 4.7kΩ pull up resistance). The LM319 datasheet state states that the saturation output voltage at I_{SINK} ≤3.2mA is typically 0.23V, and at worst 0.4V at temperatures above 0°C (I_{SINK} is the current being sunk by the LM319's output, that is Q16's collector current).

Point of saturation

We could write a formula for the PWM comparator minimum output voltage

$$V_{out,min} = V_{CEsat,Q16} + I_{SINK}R17$$

but this is not particularly useful, because we do not know the exact characteristics of the LM319's Q16 transistor. The datasheet does, however, provide a graph of the output saturation voltage, which is shown in Fig.3.

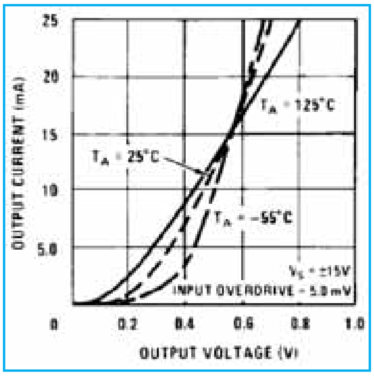

Fig.3. LM319 saturation output voltage for various output currents. In Fig.1 the current is about 3.2mA

The maximum output voltage from the PWM comparator will depend on the load, that is, any other circuitry in addition to the pull-up resistor connected to the output. In the motor controller, the PWM comparator output drives a couple of logic gates. These are included in Fig.1 to show that the comparator is not heavily loaded (the logic gates have a high input impedance). This means that the 4.7kΩ resistor will be able to pull the PWM comparator output voltage very close to the supply voltage when the LM319's output transistor is off.

The actual output voltages (high and low) of the PWM comparator are not particularly important as long as they are within the valid logic 0 and logic 1 input voltage ranges of the logic gates. The previous discussion indicates that this will be the case.

Simplified circuits

For the purpose of further analysis we can separate and simplify the two circuits. We will redraw the circuits using only the components which are essential for calculating the switching behaviour and voltage levels. If we consider a generic comparator, whose output simply switches between supply and ground, we do not need to include the 4.7kΩ resistors in these simplified circuits.

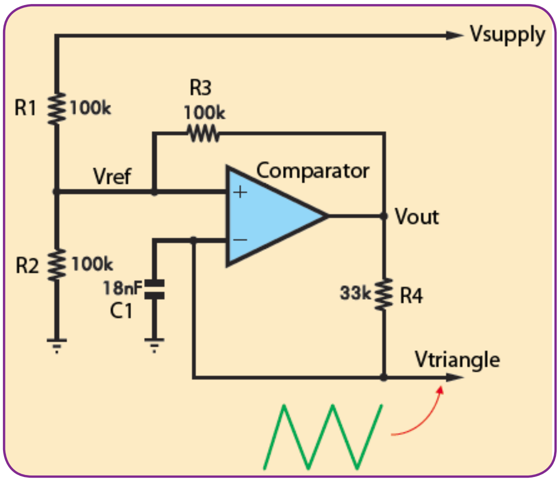

Fig.4. Simplified triangle waveform generator circuit

The 100nF supply decoupling capacitor is needed in the practical circuit to ensure proper operation of the comparator chip (particularly during switching), however, we do not need to include it in calculations relating to the switching voltages.

Similarly, the 10μF and 200pF capacitors provide some signal conditioning, but are not essential to the calculation of the switching voltages. The 10μF capacitor in particular prevents spurious switching of the comparator, but if we assume the speed control is more or less fixed, or more realistically, is changed very slowly compared to the time constant the 10μF capacitor forms with the speed setting components, then we can ignore it.

The speed control at the input to the PWM comparator is simply a potential divider (formed by VR1, the 8.2kΩ and 1kΩ resistors in Fig.1), which sets an input voltage to the comparator circuit. This voltage can be modified by the load compensation and current protection signals.

These signals are important in the context of the full motor controller, but when just considering the comparator we can ignore them. We simply need to consider an input reference voltage (the 'speed' voltage) and for our analysis it does not matter exactly how this is set.

Simplified triangle waveform generator

The triangle waveform generator is redrawn on its own in Fig.4. We now assume a generic comparator and therefore have removed the pin numbers and left off the supply connections so that the schematic only shows the components and wiring directly pertinent to our calculations. The resistors and capacitor have been labelled (R1, R2 etc) so we can write equations in terms of their values. Similarly, we label the voltages on the wires in the circuit.

Simplified comparator circuit

The circuit in Fig.5 shows the simplified version of the PWM comparator. Although Bond did not specifically ask about this, for completeness we will look at the input voltages at which the comparator switches.

Comparator ICs, such as the LM319, switch their outputs according to

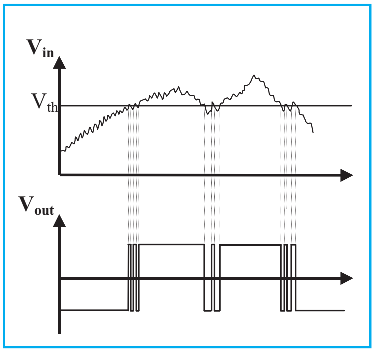

Fig.6. Comparator multiple switching problem

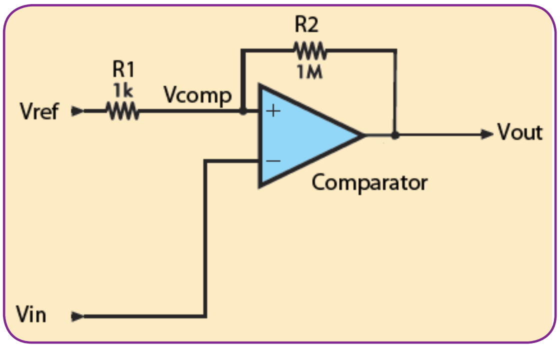

Fig.5. Simplified comparator circuit

which of their two input voltages is at the highest voltage. A potential problem with this is that the output may switch many times if the input voltages are very close, have some noise or are slowly changing. This is illustrated in Fig.6, where we assume one comparator input is fixed at V_{TH} and the other is changing.

The multiple-switching problem may be overcome by using two thresholds, eg, V_{TH} and V_{TL} (higher and lower threshold). The difference between V_{TH} and V_{TL} is called the hysteresis. When the input increases past V_{TH} the comparator switches, but it does not switch if the input decreases past V_{TH}. Instead, the input must decrease past a lower threshold V_{TL} before the comparator switches again. This is illustrated in Fig.7 and Fig.8.

A comparator with hysteresis can be made from a single simple comparator by setting the threshold depending on the comparator's current output state – using positive feedback from output to input. In the circuit in Fig.5 this is provided by R2.

Referring to Fig.5, the voltage at which the comparator switches, V_{comp}, depends on V_{ref} and V_{out}. We will assume V_{ref} is fixed (it is for a given speed of the motor controller), but V_{out} depends on the current state of the comparator. Following from our earlier discussion we assume V_{out} can take one of two values, which for simplicity we will assume to be 0V and V_{supply}.

Operation

To follow the operation of the circuit, start by assuming that V_{in} is less than V_{comp}, so $V_{out} = V_{supply}$. As V_{in} is slowly increased this condition remains until $V_{in} = V_{comp} = V_{TH}$ (higher threshold), where:

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)V_{ref} + \left(\frac{R_1}{R_1 + R_2}\right)V_{supply}$$

This equation uses the potential divider formula twice to take account of the contributions of both V_{ref} and V_{supply} to V_{comp}. Resistors R1 and R2 form a potential divider for both of these voltages (in opposite directions) and we can sum the result of the two cases (in which the other voltage is set to zero).

On switching at $V_{comp} = V_{TH}$ the output changes to V_{out} = 0V, changing the threshold to a new value, $V_{comp} = V_{TL}$ (lower threshold), where:

$$V_{TL} = \left(\frac{R_2}{R_1 + R_2}\right)V_{ref}$$

V_{out} will now stay at 0V until the input falls below V_{comp} again. The difference in the switching points, ie, the hysteresis, V_H, is:

$$V_H = V_{TH} - V_{TL} = \left(\frac{R_1}{R_1 + R_2}\right)V_{supply}$$

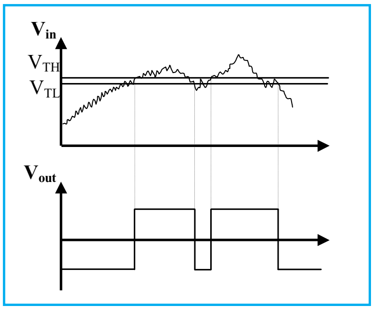

Fig.7. Using different thresholds depending on the direction of change provides clean switching

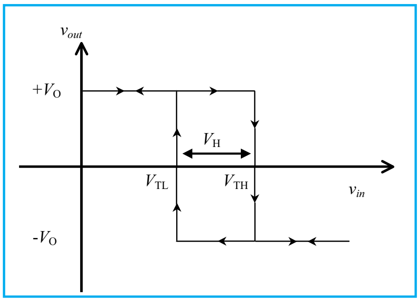

Fig.8. Switching characteristic of circuit with hysteresis. Increasing and decreasing input voltages cause the output to switch at different points

For the component values shown in Fig.5 V_H is about 15mV.

V_{ref} can be obtained from a potential divider connected to the supplies as shown in Fig.1 (VR1, the 8.2kΩ and 1kΩ resistors). Ideally, in order to prevent the comparator circuit from loading the divider, the resistance of the divider should be at least ten times smaller than the total value of comparator resistors (R1+R2 in Fig.5). We see this is the case in the motor controller circuit.

The triangle waveform generator (Fig.4) also uses a comparator with positive feedback to change the switching threshold depending on the comparator's output. The arrangement of resistors is slightly different; in fact, we could say that this circuit is like the previous one, except the reference-setting voltage divider is deliberately loaded to switch the threshold voltage.

With reference to the triangle waveform generator shown in Fig.4, the comparator output, V_{out}, will switch between the supply voltages (V_{supply} and 0V), just like the comparator chip in the PWM comparator circuit – note that the triangle waveform is the capacitor voltage, not the comparator output. When V_{out} switches, the capacitor, C1, will start charging/discharging towards V_{out} via resistor R4.

The capacitor will not charge/discharge all the way to V_{supply} or 0V because it is connected to the comparator's input and at some point it will reach V_{ref}, the voltage on the comparator's other input. When this happens, the comparator output will switch again and the capacitor will start discharging/charging in the opposite direction. Thus, the capacitor voltage will oscillate between the two values of V_{ref}, set by the R1, R2 R3 resistor network and two values of V_{out} for the comparator chip.

If we assume that comparator output voltage, V_{out}, switches between exactly V_{supply} and 0V it is straightforward to find these two values of V_{ref}. When the comparator output is 0V, R3 is effectively connected to ground in parallel with R2. The parallel value of these resistors, R_{P23}, is, using the formula for two parallel resistors:

$$R_{P23} = \frac{R_2 R_3}{R_2 + R_3}$$

This resistance forms a potential divider with R1 to set the lower of the Vref values, which is the minimum voltage for the triangle waveform, V_{WL}:

$$V_{WL} = \left(\frac{R_{P23}}{R_1 + R_{P23}}\right)V_{supply}$$

Combining this with the R_{P23} equation we get:

$$V_{WL} = \left(\frac{R_2 R_3}{R_1(R_2 + R_3) + R_2 R_3}\right)V_{supply}$$

When the comparator output is V_{supply}, R3 is effectively connected to the supply in parallel with R1. The parallel value of these resistors, R_{P13}, is:

$$R_{P13} = \frac{R_1 R_3}{R_1 + R_3}$$

This resistance forms a potential divider with R2 to set the upper of the V_{ref} values, which is the maximum voltage for the triangle waveform, V_{WH}:

$$V_{WH} = \left(\frac{R_2}{R_{P13} + R_2}\right)V_{supply}$$

Combining this with the R_{P23} equation we get:

$$V_{WH} = \left(\frac{R_2(R_1 + R_3)}{R_1 R_3 + R_2(R_1 + R_3)}\right)V_{supply}$$

The peak-to peak amplitude of the triangle waveform is simply:

$$V_{WH} - V_{WL}$$

and the offset, or centre voltage, is:

$$\frac{V_{WH} + V_{WL}}{2}$$

For the situation in Fig.4, where the three resistors values are equal (as in Fig.4) we get:

$$V_{WL} = \frac{1}{3}V_{supply}$$

and

$$V_{WH} = \frac{2}{3}V_{supply}$$

Using a 15V supply, implies a triangle waveform varying from 5V to 10V, or to put it another way, a 5V peak-to-peak waveform centred on 7.5V. This answers the other part of Bond's question.

The triangle waveform generator does not produce an ideal triangle waveform with perfect straight edges. The capacitor is charging and discharging with an exponential characteristic and the waveform therefore has this shape. However, because of the switching action of the comparator the capacitor does not follow the full charging curve and the proportion of the curve covered is a reasonable approximation to a straight line.

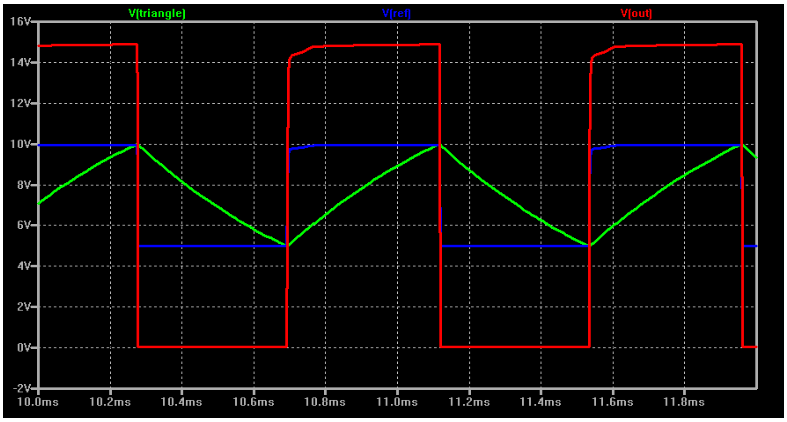

Fig.9. LTSpice simulation of triangle waveform generator in Fig.4

Simulated waveforms

Simulated waveforms of the triangle waveform generator in Fig.4, obtained using LTSpice, are shown in Fig.9. We can see V_{ref} switching between 5V and 10V, as predicted by our equations, as V_{out} switches between 0V and the supply voltage (15V). The slight curve in the triangle waveform can also be seen. However, the approximation to a triangle waveform is sufficiently good for the motor controller to operate as required.

The waveform generator will produce more accurately triangular waveforms for lower oscillation amplitudes, until the point at which other effects such as noise start to dominate. To obtain a good triangle shape of large amplitude using this circuit it would be better to set the amplitude of the generator low and amplify the signal to the required level.

The triangle output has to be connected to a high impedance input, otherwise the voltage on the capacitor will be influenced by loading effects. In the motor controller, this condition is satisfied because the triangle waveform is fed directly to the PWM comparator (LM319) input. If the triangle waveform generator was used with an amplifier, as mentioned above, a non-inverting op amp amplifier would be suitable due to its high input impedance.

During the 'upward' part of the triangle waveform the capacitor is charging from an initial voltage V_{WL} towards an applied voltage V_{supply}. After a certain time, *t*, it reaches the voltage V_{WH} and the charging process reverses. The time (*t*) taken for the capacitor to charge from V_{WL} to V_{WH} can be found from a version of the standard *RC* circuit charging equation:

$$t = R_4 C_1 \ln\left(1 - \frac{V_{WH} - V_{WL}}{V_{supply} - V_{WL}}\right)$$

in which ln is the natural logarithm. For the component values from Fig.4, and the corresponding waveform voltages calculated earlier, we get:

$$t = 33\times10^{3}\times18\times10^{-9}\ln\left(1-\frac{10-5}{15-5}\right)$$

$$= 5.94\times10^{-4}\ln(0.5) = 412\mu s$$

We can see that this is in good agreement with the simulation results in Fig.9. By symmetry the 'downward' section of the triangle is the same length, so the frequency of the triangle oscillation is:

$$f = \frac{1}{2t}$$

which gives f = 1.21kHz, reasonably close to the value of 1.25kHz stated in the original motor controller article.

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

chipKIT Arduino development

WE continue this month with a more detailed look at the chipKit Arduino development environment, and the creation of a useful project. Our processor board will be the chipKit Uno32, as this gives the best functionality and performance for its low price.

We are going to be developing two projects over the coming months; the first will be a simple project that could in theory be handled by any Arduino processor board, and is given as an easy introduction. The second will showcase the power of the PIC32 – by generating video output – and demonstrate how you can create your own library functions for Arduino.

As we hinted at last month, the chipKIT is not really a Microchip product, but the creation of Digilent. Digilent are well know for their processor and FPGA development boards, so it comes as no surprise that they should be involved in the development of a low-cost PIC32 board. The genius is in their porting of the Arduino development environment to it. Digilent are going through a process of rapid, continuous development of this IDE, MPIDE, and their latest offering (as of the beginning of Feb '12) is version 23, released on 21 December last year.

Installation

The chipKIT boards are supplied in minimalist form: no cables, no user manuals, no disks – just a link to a location on the Digilent website, from which you can download the development environment. Bear in mind this is a 122MB download, but it does include everything required – an editor, compiler, download functionality and help files.

The IDE is provided in three variants, one for each supported operating system – Windows, Mac OS X and Linux. We are looking at the Windows version only, but once installed, the operation is the same. Installation notes for the other two OSs can be found at: **www.chipkit.cc/wiki**.

The download for Windows is a zip file, located at the website **github.com/chipKIT32/chipKIT32-MAX/downloads**. This site will list the latest and some older versions of the software, for all three operating systems variants – which can make working out what you should download confusing.

At the moment the file we want is called mpide-0023-windows-20111221.zip, as this is the latest Windows

Digilent's chipKIT Uno32 board

version; by the time you come to look there may well be an updated version in place. Feel free to download either the one we specify or the latest, as it is unlikely (for the purposes of these articles) that there will be any compatibility issues between them.

Once you have downloaded the zip file, open it and extract the contents to somewhere that suits you – we placed it in c:\, giving an installation directory of c:\mpide-0023-windows-20111221. Make sure you have plenty of free space, as the zip file expands to over 460MB.

There is no installation process as such; after the files have been copied, the IDE can be started by double-clicking on the file **mpide.exe**. Right-clicking on the file and selecting sendto->Desktop will place a more convenient shortcut on your desktop. Double-clicking the shortcut or the executable will launch the IDE, see Fig.1.

The IDE

Anyone familiar with modern development environments, such as Visual Studio, Eclipse or MPLAB-X will find the MPIDE development environment rather dated and a little confusing with its basic 2D icons and strangely worded options. This is not your usual programming environment!

This is probably intentional – Arduino is designed for non-technical people, and Digilent have tried to minimise the 'complex' tools and features that are normally associated with software development tools. One major simplification is the total absence of any form of debugging support; if your code does not work perfectly first time (does it ever?) you will have to resort to the rather basic technique of putting 'print statements' into your code (be that writing text to an LCD, or flashing an LED).

There is a 'how to' on the support wiki website that explains how you can use the MPLAB development environment to perform debugging, but this is still a work in progress and is certainly not for individuals who are still learning about microprocessor development.

The main area in the IDE, coloured white, is the editor where you will type in your program (or sketch, as the Arduino community like to say). The editor supports multiple open files through tabs. A new tab can be created by clicking the 'right arrow' icon on the top right-hand side of the window. Pressing the 'New' icon or selecting 'File->New' will simply start a new copy of MPIDE. Confusing, but as most sketches are intended to be single-file designs, not a great issue.

There is an enormous amount of help available within the IDE, and it is worth going through the first four sections under the menu option 'Help' to become acquainted. You can also read through the online wiki pages, and do visit the forum if you have a specific problem.

Getting started

By far the best way to get started is by trying out some of the example programs available within the IDE; this gives you a simple introduction to the language, but also demonstrates that everything is in working order.

We start by connecting the Uno32 board to the PC using a USB cable. No external power is required; the board

Fig.1. The MPIDE Startup window

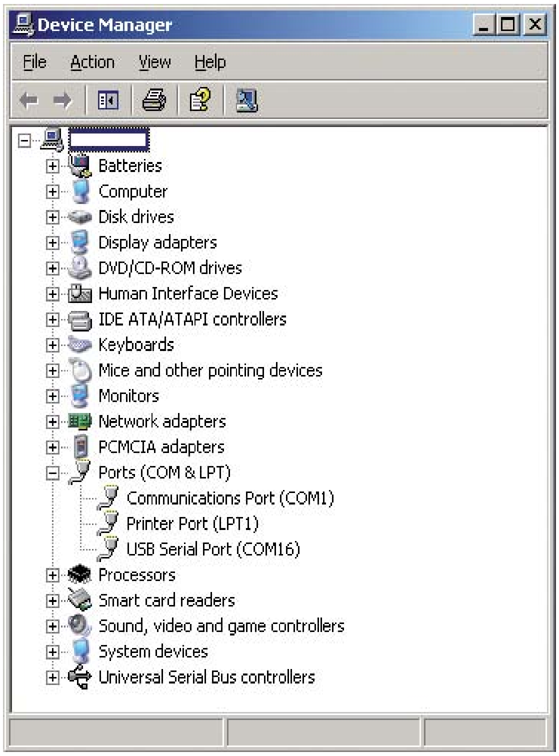

Fig.2. Find serial port

can source all its power needs from the USB interface. Once connected, the PC should recognise the USB IC on the chipKIT board and install the serial driver.

In the IDE, we can now tell it what Arduino board we are using. From the main menu select 'Tools->Board' and click on chipKIT Uno (at the top of the list). We should also tell the IDE what serial port to use to communicate with the chipKIT. The PC automatically created a serial port when you plugged the chipKIT in; you can find this port identifier from the Windows Device Manager.

Start the Control Panel by selecting 'Settings->Control Panel' from the Windows Start button. Select 'System' from the list, then click on the Hardware tab, and finally click on the 'Device Manager' button. In the Device Manager window that opens, click on the plus beside the Ports entry to see your communication ports. An example is shown in Fig. 2. As you can see here, the USB serial port is called COM16.

Back in MPIDE, select 'Tools->Serial Port'. Click on the entry for your serial port (COM16 in our example.)

This only needs to be done once, as the IDE will remember these settings when started in the future.

Example sketch

We start with one of the simplest programs; blinking an LED. From the main menu, select 'File->Examples->Basics->Blink'. There are many examples that you can play with; almost sixty in total. The Blink example gives us a nice introduction to the language, and it fits conveniently on a single page. See Fig. 3.

This shows nicely a key feature of Arduino Sketch programs; they are contained within two blocks – a **setup** block and a **loop** block. The setup block is executed once only on powering up the board; the loop block is a series of commands that will run continuously. What you put in each is entirely up to you; the chipKIT board does not care. Typically, you would put variable initialisation and port pin directions in the setup block.

The other key feature that this Sketch shows you is that the language is based very much on 'C'. The setup block is actually a C function, which takes no parameters, and returns nothing (that's what the **void** word on the start of the line means).

The language is defined fully in the Reference section under the Tools menu, but if you would like to understand how to design programs then tutorials on the C programming language would be a good place to start.

This simple program uses three library functions – pinMode(), digitalWrite() and delay(). The pinMode() function is used to set a particular I/O pin – number 13 in this case – to an output direction. digitalWrite() can then be used to set a pin high or low, and the delay() function will pause execution for the number of millseconds specified.

As you can see, there is no need to configure the processor for clock speed, operation mode etc. Nor are you required to scan the datasheet to work out what registers to write to in order to get a pin set as an output. So long as you understand what Arduino functions you can call, you can do an awfully large amount.

Toggling I/O pins is, of course, a rather simple example; we will be using some more complex features – accessing the UART and SPI libraries – but there is still significantly less to learn, as we shall find out next month when we complete out first example application.

So where are all the wonderful Arduino functions defined? All within the IDE! You can start with the Reference option under the Help menu, and the list continues if you click on the links under 'Looking for something else?'

Our first project

Our first 'Sketch' will be a device that combines a GPS receiver module and a cheap full-colour graphics display. The idea is for a handheld device that will display your altitude about sea level, and show a graph of how that changes over time. An amusing vanity gadget for mountain bikers who like to know how extreme the terrain has been.

The GPS is a small 3V module, used in a previous CameraWatch project; the display is a former Nokia telephone display, now mounted on a daughter board by Olimex and sold through Farnell (part number 170-1544) This is also a 3V device, and so should be easily connected to the Uno32.

The GPS module requires a UART interface, and the Nokia display requires an SPI interface – so we will be making use of the UART and SPI library functions within MPIDE.

What will be interesting to see is just how little knowledge of the processor and the peripheral interfaces we will need to complete this project. All will be revealed next month!

Further reading

- Diglent Website: **www.digilentinc.com**
- MPIDE download page: **https://github.com/chipKIT32/chipKIT32-MAX/downloads**
- chipKIT support forum: **www.chipkit.org/forum/**
- chipKIT wiki: **www.chipkit.cc/wiki**

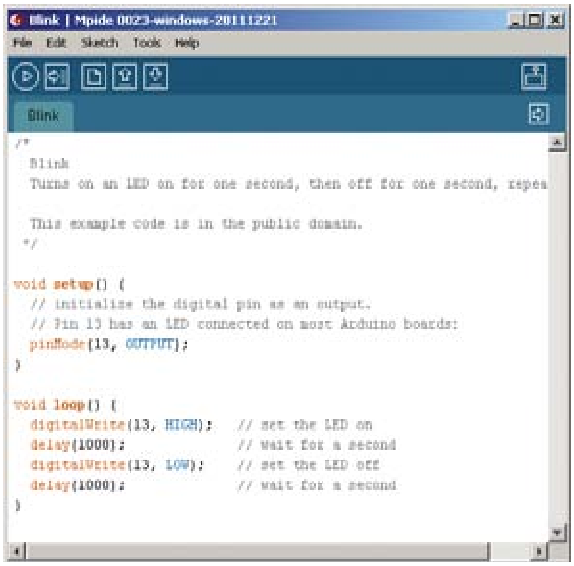

Fig.3. The Blink Sketch

Max's Cool Beans

By Max The Magnificent

On the dabble

I don't know about you, but I always like to have a couple of hobby projects on the 'back burner.' These aren't high-priority – just something I can dabble with when the mood takes me. One of my current projects is to create a diorama in an old television set.

This all came about when I spotted a TV repair shop on my travels around the city I currently call home – Huntsville, Alabama, USA. This somewhat dingy old shop was located on a back street in a less-than-salubrious part of the city. The reason it caught my eye was – well, you just don't see TV repair shops anymore.

So I wandered into the shop to chat with its owner. One of the first things I noticed hiding at the back of the shop was an old television, which – I later discovered – dated from around 1953. It turned out that over the years most of this TV's electronics (valves, coils, and suchlike) had been cannibalised to repair other sets, but the cabinet itself was in reasonably good condition, so I ended up purchasing it off him, because I had an idea.

Generally speaking, I try not to do anything nasty to old pieces of electronic equipment. However, since this TV was 'dead in the water' and there was no reasonable chance of ever getting it to work again, I didn't feel too bad about removing what was left of the electronics, including the main cathode ray tube. (I've saved any remaining vacuum tubes for 'show and tell' when I give an occasional talk to students.)

At first, I couldn't work out how to remove the glass from the front so I could clean it and also reach inside to work on my diorama from the front. I knew that there had to be a way, because I'm sure that screens were occasionally damaged and it would be silly to expect the repair man to disassemble everything just to replace the protective glass panel. And then, when I was moving the cabinet around the garage, I grasped the strip of wood at the top of the screen and felt a screw hidden under the overhang. There are three such screws, and I am sure that if I remove them I'll be able to easily lift the glass out to allow me to play around.

Max the caveman

So what am I going to create a diorama of? Well, I'm thinking of creating a caveman scene similar to one I ran across in images on Google. In my case, the side of the cave closest to us will be the TV screen, so the 'entrance' to the cave will be located toward the back of the set

Of course, I'm not going to replicate this particular scene, but I do like the general idea. I'm thinking of having a wood fire in the middle of my cave, with folks sitting around it (I can use flickering LEDs to give a fire effect).

Of particular interest are the mountains and sky and so forth that you can see through the entrance to the cave. In this example, they are painted onto a backdrop. In my case, however, I'm planning on having a flat-screen LCD mounted on the back of the TV set. I will use a cheap-and-cheerful notepad computer to drive this, which will allow me to display a variety of different scenes, as required.

An example caveman diorama, as seen on Google

In fact, I could tie this to the time of day, so that daytime and nighttime in the real world are mirrored in the model. I could have clouds gradually moving across the sky in the day; and then a huge moon, shooting stars and fantastic images of the Milky Way visible at night. I could also present really amazing lightning displays in the model when it's storming outside my house in the real world. Maybe I could go one further and map events seen through the entrance to the cave in the model onto the four seasons in the real world (snow in the winter, and so on and so forth).

On the rocks

I've been meandering around the Internet looking at different images of caves, just to gather some thoughts about different structures, the shaping of the walls, textures and colors and suchlike. My problem is that I'm wondering how to obtain a realistic-looking rock texture for my model. As a first pass, I'm planning on creating a framework out of chicken wire, overlaying this with *papier mâché*, and painting it to look like rock. The only problem is that I've never done anything like this before, so I'm not sure how it will turn out.

I have looked on Amazon for books on creating dioramas and landscapes for railway models, but each one I've found thus far has had mixed reviews – some folks say 'this is great', while others say 'this is rubbish' or 'you can't get these materials anymore'; none of which is tremendously encouraging.

But the main thing is I'm having a lot of fun planning this and experimenting with different techniques. And I really cannot wait until the diorama itself is complete and I can start to experiment with displaying different scenes on the computer screen in the background.

Until next time – have a good one!


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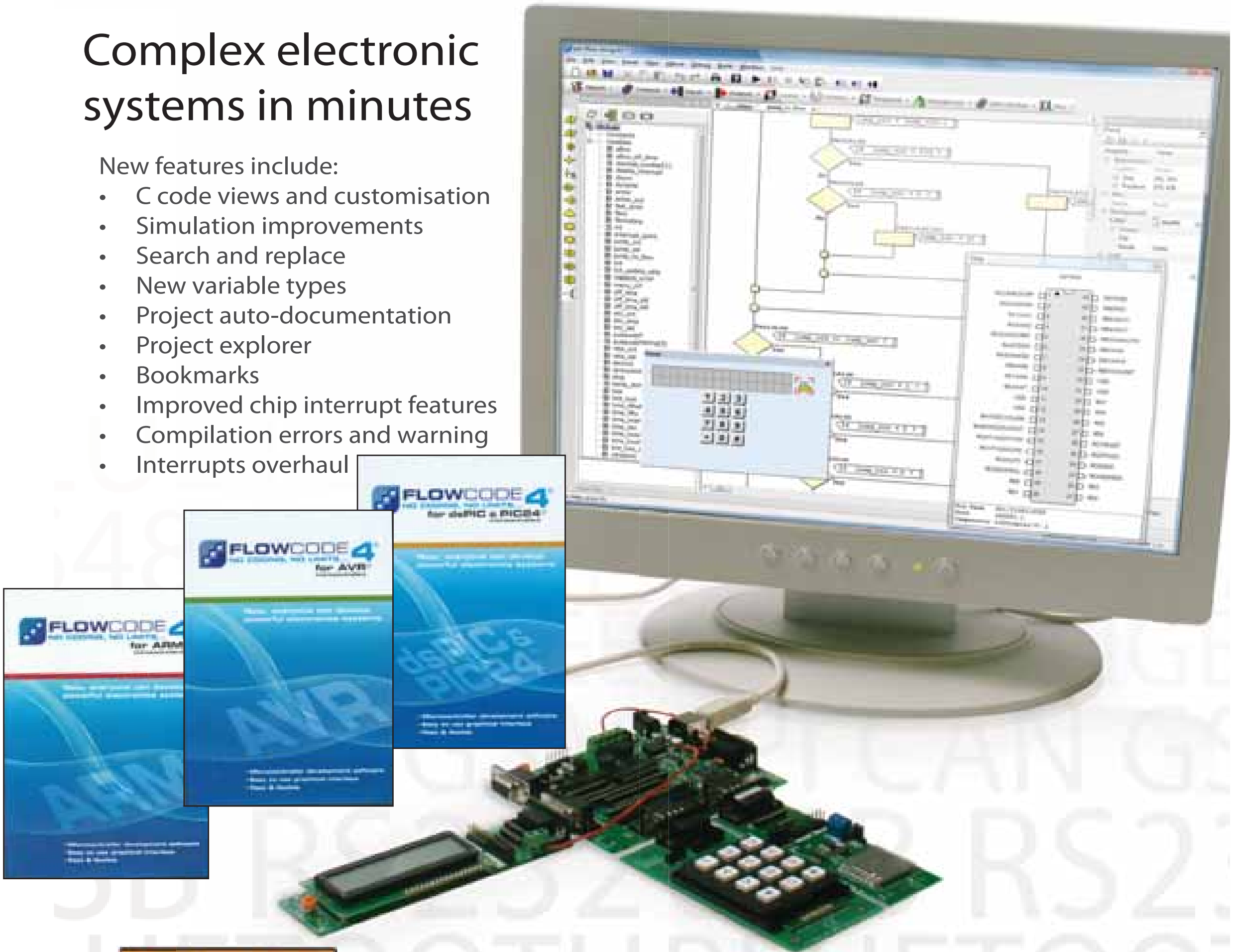

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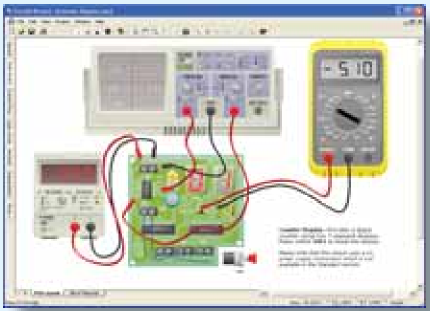

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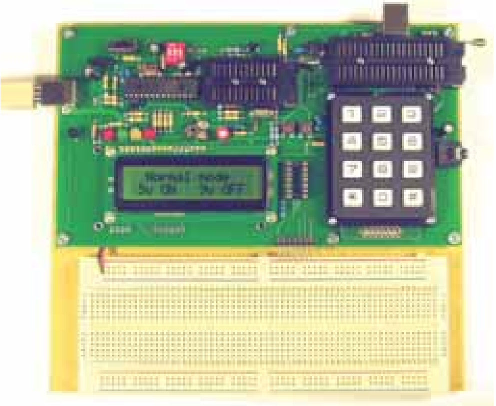

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The second half of *Experimenting with Serial Communications* 4th Edition starts with an introduction to our Easy USB. Then we repeat some of the serial experiments but this time we use a PIC18F2450 with its own USB port which we connect directly to a USB port of your PC. We follow this with essential background study then work through a complete project to use a PIC to measure temperatures, send the raw data to the PC, and use the PC to calculate and display the temperature.

Easy USB is a perfect solution for simple and medium complexity project. For complex projects or where the timing is critical it is best to split the action between two or more PICs. In the last chapter of the book we complete the study by learning how to use the library routines to programme a PIC18F2450 as a USB to USART converter.

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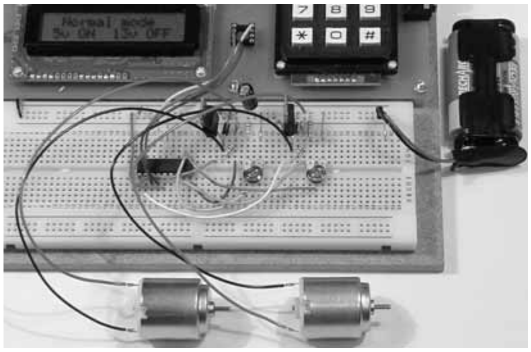

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NET WORK

by Alan Winstanley

Clocking your car

THIS month's *Net Work* examines some of the issues surrounding our online privacy, and considers the trends emerging in real-time image analysis.

Back in the February column, I highlighted a high-resolution webcam (the HD 720p Logitech 9000) that is typical of many high quality USB cameras now on sale. Apart from Skyping or capturing video in a much higher resolution than its predecessors, Logitech's HD camera can scan and recognise barcodes and QR codes in a trice, helped by appropriate software. Like similar webcams, it can also 'recognise' faces of subjects to track their motion, or superimpose fun effects on the subject by locating their basic facial features and playing tricks with the image.

A number of digital and video cameras use facial recognition to detect smiles, motion or blinking, to help the user take a shot at the optimum time. Facial recognition is not new, but it is part of the technological trend of analysing images and doing more intelligent things with the data. Indeed, some ten years ago I reported on a trial experiment in which the faces of pedestrians or passers-by were scanned (at, say, an airport check-in) by cameras which tried to compare them against a database of photos of criminals, or persons who interested the authorities.

The state of the technology, bandwidth and computing capacity made the idea barely usable at the time. However, by the mid 2000s, facial recognition was evolving with mobile applications being deployed by the US police. Systems could then analyse biometric data, including facial features, skin textures, fingerprints and iris patterns more successfully.

Licensed to fine!

Since then, digital camera and image processing technologies have jumped in their capabilities. Computer users who own a flatbed scanner will know of OCR (optical character recognition), in which software is used to convert printed text into computer data. In a Tesco supermarket car park recently, my mobile phone detected the Wi-Fi network used by Tesco's ANPR (automatic number plate recognition) cameras. The car-park cameras 'clock' (scan) visitors when they arrive and images are transmitted wirelessly to a central system where the number (license) plates can be scanned and recognised.

Overseas readers might be surprised to know that any shopper unfortunate enough to overstay their three-hour visit receives a £70 ($110) penalty notice in the mail, helped by the UK car licensing authority (the DVLA) which plays fast and loose with our details. It happily releases citizens' data in relation to civil disputes, such as private car-parking infringements, in a breach of personal privacy that many seem to shrug off and accept. This is highly symptomatic of how we have slowly allowed our data privacy to be eroded.

In Tesco's favour, UK readers having a Tesco Clubcard can now register for Tesco's free Wi-Fi (available in Extra stores only) by entering their Clubcard number in their device's Wi-Fi setup. See: **www.tesco.com/clubcard/wifi/**). The setup was a doddle but, strangely, although my phone clearly connects, I have yet to be able to check POP3 email successfully using Tesco Wi-Fi.

Car number plates are not the only thing that can be scanned and recognised by computer systems. Google Images has long offered a simple image search, which displays a gallery of image thumbnail 'hits' in response to a search query. You can also drag an image from your hard disk onto the Google Image Search box at **http://images.google.com/** and Google will search the web for any matches. However, I couldn't make this feature work when I tested it.

Photos and graphics published on the web are also indexed by several third-party websites, including TinEye (**www.tineye.com**). Their 'Reverse Image Search' endeavours to match the pattern of pixels in an image to generate a hit-list of matches from around the web. You can download the TinEye web browser plug-in to streamline this search in your web browser.

The Israeli firm PicScout, now owned by Getty Images, uses sophisticated image-scanning technology to pinpoint on the web any copies that match Getty's library of 25 million images. The scanning techniques also sniff out distorted, cropped, reversed or Photoshopped images. Potential infringers may face an expensive claim for breach of copyright, one reason why properly accounted-for 'royalty free' (RF) images should be used on websites: it's wise to keep records of their sources for ever (tip: upload license details to the cloud as well, as described last month).

Google Search can find air flights to suit, and suggest prices (US only)

Looks Familiar

You might wonder where real-time 'reading and recognising' of online images might lead, especially if you mix into this the relentless trends in social networking. It's an area that is dedicated to joining up the dots between users, often without them giving a second thought about any future implications. Speaking personally, I still have deep reservations about Facebook, as I worry about the way in

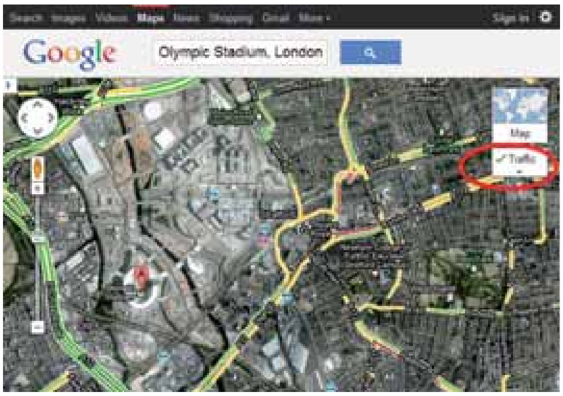
which I feel some users eagerly lay bare their lives without thinking about the possible consequences.

Facebook is heading towards an IPO valuing it at $75 billion. It previously had its knuckles rapped in Europe and the US over the way it changed default privacy settings without users' prior consent. Many users post all sorts of personal details and photos on Facebook, and its name-tagging feature (which can be disabled) can automatically suggest the names of friends, based on Facebook's system for comparing photos that have been 'tagged' with a name. The tags could be seen by certain other Facebook users (eg, friends of the person you just tagged), depending on your privacy settings.

The privacy options are much too complicated to explain here, so if you want to know all about Facebook and name tags, go to **http://tinyurl.com/79326tk**. A chart showing the maze Facebook users had to navigate to understand their 50+ Facebook privacy settings was published online in 2010 by the *New York Times* at: **http://tinyurl.com/2umddlb**.

Google too has been dabbling with image analysis since 2006, when it bought the specialist firm Neven Vision to help solve the problem of recognising objects contained in images. That's why Google Street View can automatically pixelate vehicle number plates and human faces in images to protect privacy. Other than that, Google has wrestled with the thorny problems of privacy for some time, and it recently decided to roll up no less than 60 different privacy policies into one. Their own name-tagging feature was originally pencilled into Google's Picasa photo album-sharing site in 2008. The latest Picasa 3.9 lets you share name tags on the Google+ social network, but only if the subjects of the photo agree. See **http://tinyurl.com/7t5rwgo** for details.

Google continues in its quest to connect everyone to everything, whether we need it or not. Often, existing data is aggregated into a human-recognisable format. For example, in the US you can use Google Search to check airline flights and compare prices, refining your search by airline, the number of stops or the date. Google has also expanded its real-time road traffic maps to show traffic flow on major routes around the world. Road congestion can be seen in Google Maps by enabling the Traffic layer, which can be superimposed over the satellite image or map. Traffic densities are shown by coloured routes changing from green to red/black. My screenshot shows a Google Map view of the roads around the brand new London 2012 Olympics stadium. And of course, you can download in-car or walking navigation instructions courtesy of Google as well.



Select the Traffic layer (ringed) in Google Maps to view real-time traffic density (major locations only)

Voice recognition of search requests is also heading our way – Apple offers Siri on its iPhone 4S and Google's answer for Android is dubbed Majel. The latest desktop-based speech-recognition programs such as Nuance's Dragon Naturally Speaking are said to be fantastically good, although mobile products such as Apple's Siri have some way to go, especially if you talk with a heavy accent. The moment has arrived when, after giving it a little training, you can ask a device some questions or utter commands, and a mobile smartphone or web browser will respond directly with the answer. Facial and gesture recognition software and hardware are improving all the time and some audio-visual software can actually lip-read. Isn't that something?

Cookie monster

It's no coincidence that when I checked numerous websites, any that carried Google Adsense adverts displayed an ad from a UK-based PC vendor whose website I'd visited recently. Google's highly-tuned advertising machinery ensures that focused advertisements can be targeted throughout its network. As another sign of how Internet users shrug about their online privacy, 'persistent cookies' can be dropped onto the PC when visiting many websites, often without one's direct knowledge. (By contrast, a 'session cookie' disappears after you leave the website, eg, for online banking.) Cookies are generally benign and although an individual cannot be personally identified from them, they can help to feed your surfing profile to online advertisers resulting, in my case, in a targeted advert from a PC supplier, together with (joy) a money-off voucher code. Cookies also help websites to remember your preferences.

Changes in European law (enshrined in the UK's Privacy and Electronic Communications Regulations) are in the pipeline that control how cookies may be dropped onto a visitor's computer or mobile device. A subtle change of law means that users' consent would be needed if cookies were used. One hope is that web browsers will be updated, enabling users to configure the sort of cookies they wish to receive. Work on this aspect is ongoing.

If cookies are not a privacy issue, then you might be unnerved by the principles of Geo IP, or Geographical IP, in which a user's physical location is estimated from IP data and other records for anti-fraud, visitor profiling or marketing purposes. One Geo IP specialist MaxMind (**www.maxmind.com**) says of its service, *'We employ user-entered location data from sites that ask web visitors to provide their geographic location. We then run millions of these datasets through a series of algorithms that identify, extract, and extrapolate location points for IP addresses.'*

MaxMind supplies Geo IP services for online marketing and anti-fraud purposes. Try their demo

The free demo: **www.maxmind.com/app/locate_my_ip** showed my IP address and ADSL supplier's name, my county and exact town name, and it had a pretty good guess at my longitude and latitude, although another Geo IP site got my location laughably wrong. These on-the-fly results can help to profile an actual Internet user like no cookie can. Geo IP methods can 'tune' online advertising to deliver local-interest ads that will appeal to individuals: if you're in New York you might see banner ads imploring you to eat more New York bagels, but if you live in London you might see ads for London Olympics attractions instead.

I hope you enjoyed this month's *Net Work*. We love to hear from readers, and you can email me at **alan@epemag.demon.co.uk** or write to **editorial@wimborne.co.uk** for possible inclusion in *Readout*.

READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

WIN AN ATLAS LCR ANALYSER WORTH £79

An Atlas LCR Passive Component Analyser, kindly donated by Peak Electronic Design Ltd, will be awarded to the author of the Letter Of The Month. The Atlas LCR automatically measures inductance from 1mH to 10H, capacitance from 1pF to 10,000µF and resistance from 1Ω to 2MΩ with a basic accuracy of 1%. www.peakelec.co.uk

All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

☆ LETTER OF THE MONTH ☆

SI prefixes for the uninitiated

Dear editor
Newcomers to hobby electronics may be confused by the large number of prefixes to the basic units we tend to use. For most practical purposes, the units for frequency (the hertz, abbreviated to Hz), capacitance (the farad, F), resistance (the ohm, Ω) and current (strictly the ampere, but universally called 'amp', A) are almost always used with prefixes, because the basic unit is either too small or too big to be used on its own. Only the unit for voltage (the volt, V) is commonly used without a prefix, unless of course you're a high-voltage person and regularly work in kV.

Probably the first prefixes you will learn are 'milli' (one thousandth, for milliamp, usually abbreviated to mA), 'kilo' (1000, as in kΩ), and 'mega' (one million, as in MHz for megahertz). Here's a useful reference table of all the 20 internationally-agreed prefix symbols and their meanings, as defined by the International System of Units (SI). These are used to form decimal multiples and submultiples of SI units.

Y	yotta	1,000,000,000,000,000,000,000,000	10^{24}
Z	zetta	1,000,000,000,000,000,000,000	10^{21}
E	exa	1,000,000,000,000,000,000	10^{18}
P	peta	1,000,000,000,000,000	10^{15}
T	tera	1,000,000,000,000	10^{12}
G	giga	1,000,000,000	10^{9}
M	mega	1,000,000	10^{6}
k	kilo	1,000	10^{3}
h	hecto	100	10^{2}
da	deka	10	10^{1}
d	deci	0.1	10^{-1}
c	centi	0.01	10^{-2}
m	milli	0.001	10^{-3}
µ	micro	0.000,001	10^{-6}
n	nano	0.000,000,001	10^{-9}
p	pico	0.000,000,000,001	10^{-12}
f	femto	0.000,000,000,000,001	10^{-15}
a	atto	0.000,000,000,000,000,001	10^{-18}
z	zepto	0.000,000,000,000,000,000,001	10^{-21}
y	yocto	0.000,000,000,000,000,000,000,001	10^{-24}

Note the use of some upper case and some lower case letters for the prefixes. These should be strictly adhered to for correctness, and this avoids confusion between, for example, mega (M) and milli (m), which, of course, are separated by a factor of 10^9. You often see these prefixes used wrongly in the popular press.

There is also a risk of confusion between k for kilo, denoting 1000 (that is 10^3) and 1024 (2^{10}), and also M for mega, denoting 1,000,000 (10^6) and 1,048,576 (2^{20}), often used in the unit megabyte. These latter definitions, employing powers of 2, are commonly used where binary arithmetic is common, such as in computing to define an amount of memory in a computer, or the capacity of a hard drive. Hard drives are becoming so dense nowadays that they are starting to be measured in terabytes.

Large to small

When I first got interested in electronics in the 1960s, pF (for picofarads) hadn't quite gained common use. You could see in magazine articles and marked on capacitors, some number of µµF for the value of the capacitor, that is a million-millionth of a farad, which is, of course, a pF, which we always use today.

The prefixes most commonly used now in electronics and radio are in the range (from large to small) – giga (usually to denote an extremely high frequency in GHz) to femto (sometimes used to denote an extremely low current in fA, or a very small capacitance in fF).

With the full list shown earlier, you are now prepared for the day when we will be commonly working in yottahertz (YHz, 10^{24} Hertz) and yoctoamps (yA, 10^{-24} A). Well, maybe not yoctoamps, it's the current caused by the passage of one electron every two days!

In electronics, hecto, deka, deci and centi are rarely used, so if you need a 10Ω resistor, don't go asking for a dekaohm resistor because you'll be met with a blank stare.

Stef Niewiadomski, by email

Matt Pulzer replies:

Thank you Stef, a most useful summary – and I certainly agree about errors in the popular press (and often press that should know better) – they get it wrong on a regular basis. For me, it's the written equivalent of squeaky chalk on a blackboard.

I'd like to add a few more points. Even if the unit is name based, for example newton, hertz or tesla, or name derived such as volt (Volta) or amp (Ampère) – it is written with lower case (apart from at the start of a sentence). Only ever pluralise the written out version, never the abbreviated unit – volts is fine, Vs means volt-second.

Nobel prizes are two a penny, they hand them out every year! If you really want to be honoured in science, then having a unit named after you is about as good as it gets. And the top honour is to have a fundamental unit named after you.

Choosing which physical properties are 'fundamental' is to some extent an arbitrary decision based on what is easy to measure – or simply too useful to be avoided, but in the SI system it is mass, length, time, absolute temperature, electrical current, luminous intensity and 'amount of a substance'. The units are kilogram (kg), metre (m), second (s), kelvin (K), ampere (A), candela (cd) and mole (mol). Of these, only the Scotsman Lord Kelvin and Frenchman André-Marie Ampère took top billing.

The other units are not based on names. 'Gram' comes from the Latin gramma, *meaning a small weight. 'Metre' comes from the Greek* metron, *which simply means a 'measure', as in 'metrology', the scientific study of measurement. 'Second' comes from the Latin* secundus, *the second division of the hour (after minute) – the same system we use today. Mole is a relatively new unit and comes from the German* Molekul. *Candela is another Latin word, which simply means candle.*

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The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

The Microchip items are: MPLAB Integrated Development Environment V8.20; Microchip Advance Parts Selector V2.32; Treelink; Motor Control Solutions; 16-bit Embedded Solutions; 16-bit Tool Solutions; Human Interface Solutions; 8-bit PIC Microcontrollers; PIC24 Mircrontrollers; PIC32 Microcontroller Family with USB On-The-Go; dsPIC Digital Signal Controllers.

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BUILD YOUR OWN PC – Fourth Edition
Morris Rosenthal

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Through 150 crisp photographs and clear but minimal text, readers will confidently absorb the concepts of computer building. The extra-big format makes it easy to see what's going on in the pictures. The author goes 'under the hood' and shows step-by-step how to create

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

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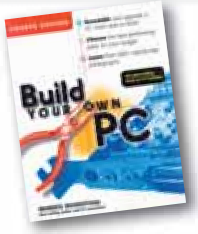
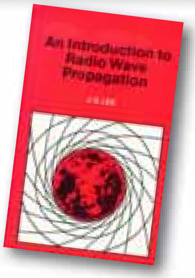


a Pentium 4 computer or an Athlon 64 or Athlon 64FX, covering: What first-time builders need to know; How to select and purchase parts; How to assemble the PC; How to install Windows XP. The few existing books on this subject, although outdated, are in steady demand. This one delivers the expertise and new technology that fledgling computer builders are looking for.

224 pages - large format **Order code MGH2** **£16.99**

RADIO



AN INTRODUCTION TO RADIO WAVE PROPOGATION
J.G. Lee

Radio wave propogation is one of the more important discoveries made in the early 20th century. Although technology lagged behind early experimenters pursued this newly discovered phenomenon eagerly for, in understanding the physics of propagation, they were discovering more about our Universe and its workings.

Radio wave propagation has its origins in the world of solar physics. The Sun's radiation provides the mechanism for the formation of the ionosphere. How the ionosphere is formed, and how it provides long-distance communication, is carefully explained. Non-ionospheric propagation, including 'moonbounce' or satellite communications, is covered as well.

This book has been written with the average electronic hobbyist in mind. Technical language and mathematics have been kept to a minimum in order to present a broad, yet clear, picture of the subject. The radio amateur, as well as the short-wave listener, will find explanations of the propogation phenomena which both experience in their pursuit of communications enjoyment.

116 pages **Order code BP293** **£4.45**

THEORY AND REFERENCE

BEBOP TO THE BOOLEAN BOOGIE
Second Edition
Clive (call me Max) Maxfield

This book gives the “big picture” of digital electronics. This in-depth, highly readable, guide shows you how electronic devices work and how they’re made. You’ll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You’ll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it’s used. And there’s much, MUCH more. The author’s tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate.

Contents: Fundamental concepts; Analog versus digital; Conductors and insulators; Voltage, current, resistance, capacitance and inductance; Semiconductors; Primitive logic functions; Binary arithmetic; Boolean algebra; Karnaugh maps; State diagrams, tables and machines; Analog-to-digital and digital-to-analog; Integrated circuits (ICs); Memory ICs; Programmable ICs; Application-specific integrated circuits (ASICs); Circuit boards (PWBs and DWBs); Hybrids; Multichip modules (MCMs); Alternative and future technologies.

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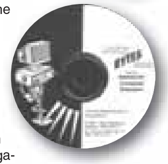
BEBOP BYTES BACK (and the Beboputer Computer Simulator) CD-ROM
Clive (Max) Maxfield and Alvin Brown

CD-ROM



This follow-on to Bebop to the Boolean Boogie is a multimedia extravaganza of information about how computers work. It picks up where “Bebop I” left off, guiding you through the fascinating world of computer design . . . and you’ll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the CD-ROM contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the CD-ROM contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. If you’re the slightest bit interested in the inner workings of computers, then don’t dare to miss this!

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Martin Bates

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Interfacing PIC Microcontrollers provides a thorough introduction to interfacing techniques for students, hobbyists and engineers looking to take their knowledge of PIC application development to the next level. Each chapter ends with suggestions for further applications, based on the examples given, and numerous line drawings illustrate application of the hardware.

Step-by-step examples in assembly language are used to illustrate a comprehensive set of interfaces, and these can be run interactively on circuit simulation software, used to aid understanding without the need to build real hardware.

A companion website includes all examples in the text which cam be downloaded together with a free version of Proteus’s ISIS Lite.

298 pages | **Order code NE48** | **£30.99**

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R. A. Penfold

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102 pages | **Order code BP239** | **£5.49**

OPERATIONAL AMPLIFIER USER’S HANDBOOK
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208 pages | **Order code PC121** | **£7.95**

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Ian Waugh

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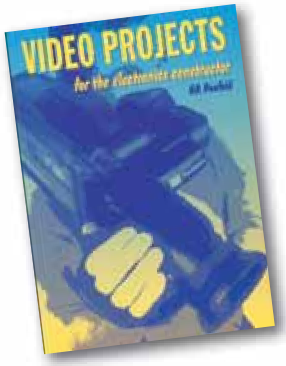

ELECTRONIC PROJECTS FOR VIDEO ENTHUSIASTS
R. A. Penfold

This book provides a number of practical designs for video accessories that will help you get the best results from your camcorder and VCR. All the projects use inexpensive components that are readily available, and they are easy to construct. Full construction details are provided, including stripboard layouts and wiring diagrams. Where appropriate, simple setting up procedures are described in detail; no test equipment is needed.

The projects covered in this book include: Four channel audio mixer, Four channel stereo mixer, Dynamic noise limiter (DNL), Automatic audio fader, Video faders, Video wipers, Video crispener, Mains power supply unit.

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You’ll learn about recording techniques, software and effects, mixing, mastering and CD production.

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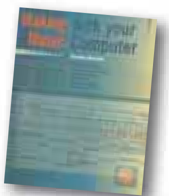

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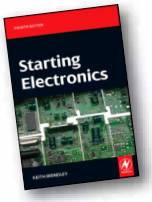

HOW ELECTRONIC THINGS WORK – AND WHAT TO DO WHEN THEY DON'T
Robert Goodman
You never again have to be flummoxed, flustered or taken for a ride by a piece of electronics equipment. With this fully illustrated, simple-to-use guide, you will get a grasp on the workings of the electronic world that surrounds you – and even learn to make your own repairs.

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394 pages **Order code MGH3** **£21.99**

PIC IN PRACTICE (2nd Edition)
David W. Smith
A graded course based around the practical use of the PIC microcontroller through project work. Principles are introduced gradually, through hands-on experience, enabling hobbyists and students to develop their understanding at their own pace. The book can be used at a variety of levels.

Contents: Introduction to the PIC microcontroller; Programming the 16F84 microcontroller; Introductory projects; Headers, porting code – which micro?; Using inputs; Keypad scanning; Program examples; The 16C54 microcontroller; Alphanumeric displays; Analogue to digital conversion; Radio transmitters and receivers; EEPROM data memory; Interrupts; The 12 series 8-pin microcontroller; The 16F87X microcontroller; The 16F62X microcontroller; Projects; Instruction set, files and registers; Appendices; Index.

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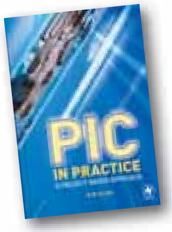

PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING
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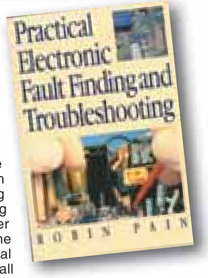

The fundamental principles of analogue and digital fault finding are described (although, of course, there is no such thing as a "digital fault" – all faults are by nature analogue). This book is written entirely for a fault finder using only the basic fault-finding equipment: a digital multimeter and an oscilloscope. The treatment is non-mathematical (apart from Ohm's law) and all jargon is strictly avoided.

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BUILDING VALVE AMPLIFIERS
Morgan Jones
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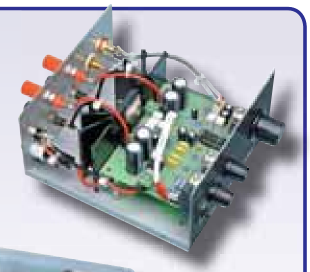

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A High-Quality Digital Audio Signal Generator – Part 3

In the March and April 2012 issues, we described the design and construction of our new Digital Audio Signal Generator. The final article next month has the driving instructions.

MAY '12 ISSUE ON SALE 5 APRIL 2012

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